

Discovering Sites Unseen

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INTRODUCTION

Growing concern exists among archaeologists about the methods and techniques used to discover archaeological sites, reflecting increasing interest in regional analysis and archaeological resource management. Newly explicit attention to site discovery owes much to the requirements of contemporary archaeological resource management, which has as one of its general goals an understanding of the full range of archaeological resources, not simply those most easily found or already known (King *et al.* 1977:105ff.; Schiffer and Gumerman 1977:211ff.). The attention, however, is not limited to resource management concerns or to archaeology in the United States (e.g., Dyson 1978:253–255, 1982; Ammerman 1981:64–5, 81). Archaeological research of any sort that uses survey data from regions where site discovery is difficult must confront and resolve, or at least acknowledge, discovery problems.

Recent articles discuss site discovery problems generally and provide both a widely applicable framework for deriving solutions to specific discovery problems and specialized concepts and a vocabulary for discussing such problems (S. Plog *et al.* 1978; Schiffer *et al.* 1978). Two of these concepts, *visibility* and *obtrusiveness*, are central to the identification and solution of discovery problems. *Visibility* is a characteristic of the modern environment in which a site is located. It refers to the extent to which a site has been buried or covered by soil aggradation and vegetation since its last occupation (Schiffer *et al.* 1978:6–7). Visibility, for example, is high in a region where vegetation is sparse and soil aggradation has been minimal. In such regions, sites on the present ground surface will be visible. Visibility is low in densely vegetated areas or where soil aggradation has been common, such as an uncultivated meadow, a forest, or a floodplain. In regions with these characteristics, sites will be buried and generally undetectable on the modern surface by the naked eye.

A site's *obtrusiveness*, on the other hand, depends upon its contents and the discovery technique used to detect it (Schiffer *et al.* 1978:6). Consider first the effect of site contents upon obtrusiveness. Large sites with dense and widespread contents or architectural remains are relatively obtrusive. When they are on or near the surface, such sites are highly obtrusive. They can be detected by many techniques so the easiest and the least-expensive technique can be chosen to discover them. Highly obtrusive sites, such as Midwestern mound complexes, thick eroding shell middens in coastal areas, Iroquois village sites in plowed fields, or large Southwestern habitation sites with architectural remains, are hard to miss. Simple intensive pedestrian survey using only visual inspection probably will discover sites with such characteristics. Many, probably most, sites are not highly obtrusive, however. Nor does the inclusion of a few highly obtrusive remains guarantee that a site will be discovered. Even a site with some obtrusive contents might go undiscovered because of poor visibility or an insufficiently intensive application of a discovery technique. Where visibility is hindered by vegetation and soil aggradation, the discovery of sites or portions of sites with relatively unobtrusive contents requires more complicated, time-consuming, and expensive techniques. The goal of using these special techniques is to increase the obtrusiveness of the sites so that they can be discovered.

A wide range of techniques has been or could be used to discover sites, though not all techniques are equally effective for all kinds of archaeological remains. Nor are all techniques suited for the full range of

study-area sizes, environmental conditions, or project budgets. Confronted by the variety of possible techniques, each with varied capabilities and limitations, archaeologists must choose carefully when designing a discovery investigation.

The aim of this chapter is to provide some guidance for this decision making, either directly or by directing readers to appropriate references. In the following sections a number of techniques are described and their effectiveness, considering the kinds of remains they can detect and their logistical limitations, is discussed. As readers will see, my research and interest in the archaeology of Northeastern North America, where sites tend to be unobtrusive and visibility low, clearly pervades this article. The emphasis here is upon the effectiveness of a variety of techniques for the discovery of sites with unobtrusive contents in environments where visibility is poor and subsurface testing frequently necessary. Nevertheless, the effectiveness of technique given other remains and circumstances also is touched upon.

The identification of one or two discovery techniques that can be applied universally is not the goal of this study. On the contrary, it is recognized from the start that project goals, schedules, budgets, and environmental constraints, in addition to the variety of discovery techniques and methods of deploying them, tend to make each project's discovery problems and their solutions unique. It would be inappropriate to suggest a discovery technique for use in all situations. On the other hand, it is important to point out the strengths, weaknesses, assumptions, and constraints embodied in different techniques so that they can be considered accurately for use in specific situations.

The focus here is upon site discovery, not site examination or excavation. The latter two activities are site-specific and occur only after a site has been discovered. Their goals are to determine the size, shape, structure, and contents of a site. A number of recent articles that address various concerns for site-specific investigations of subsurface sites can be consulted regarding this topic (e.g., Asch 1975; Brooks *et al.* 1980; Brown 1975; Carr 1982; Chartkoff 1978; Chatters 1981; Dekin 1976, 1980; Knoerl 1980; Nance 1981; Newell and Dekin 1978; Rice *et al.* 1980; Versaggi 1981). Site discovery, on the other hand, focuses on a study area with the goal of locating all or a sample of sites within it. Often a technique applicable for discovery will be inappropriate for examination, and vice versa. By analyzing a number of techniques I hope to suggest whether they are useful for site discovery, examination, or both, as well as the general vegetation and topographic conditions under which each will be effective. Many of the techniques considered in this chapter are of limited effectiveness for the discovery of sites. In some cases this is due to the types of remains that the techniques are able to detect; in others it is caused by logistical or visibility problems.

A related aim of this chapter is to assemble a bibliography, albeit far from comprehensive, referencing useful but often obscure or limited-distribution reports and papers that throw light on the topic of site discovery. The bibliography serves also to point readers to fuller descriptions of the techniques. This is especially so for the more technically sophisticated techniques, many of which are not effective for the discovery of sites lacking either structural remains, or dense and abundant features, or anthropic soil horizons.

This article is, to my knowledge, the first extensive comparative study of site-discovery problems and specific techniques. Although many archaeologists have confronted the problem in specific situations, they have not faced the problem of general comparisons of techniques. For this reason there is little comparative information about different techniques and no existing framework for evaluating the effectiveness of different techniques. Where the former exist I have incorporated them here. To serve as a framework for evaluating effectiveness, I have developed a crude model of the abundance and intrasite

distribution of the constituents of archaeological sites. As with all modeling, this involves both generalizations and some speculation.

The ability of each technique to detect various site constituents is a measure of its effectiveness for discovering different kinds of sites. If a technique cannot detect or is a poor detector of some constituents, sites with these constituents will be unobtrusive; they ordinarily will not be discovered using this technique. The effectiveness of any technique as a means of site discovery depends upon its ability to detect at least one of the constituents held in common among the sites being sought. The capability of the technique, however, is only one requirement for effective site-discovery. The detectable constituent(s) must occur commonly among the sites sought as well as be abundant and widespread enough within these sites to be intercepted and identified, given the specific application of the technique.

The next section considers these latter aspects of site obtrusiveness: intersite frequencies of site constituents and their intrasite and abundance distribution. Subsequent sections describe various techniques that have been or might be used to discover sites. The usefulness of each technique for site discovery is evaluated considering the constituent(s) it can detect as well as its logistical requirements.

THE CONSTITUENTS OF SITES

The archaeological record can be thought of as a more or less continuous spatial distribution of artifacts, facilities, organic remains, chemical residues, and other less-obvious modifications produced by past human activities (Dancey 1981:17–28; Dincauze *et al.* 1980:63–70). The distribution is far from even, with large areas where archaeological remains are infrequent and widely dispersed (e.g., Thomas 1975). There are other areas, however, where materials and other remains are abundant and clustered. It is these peaks of abundance and clustering in the archaeological record that commonly are referred to as *sites* (Dancey 1981:20).

For heuristic purposes and cultural or behavioral interpretations, archaeologists frequently describe sites as the loci of past human activities (e.g., Hester *et al.* 1975:13; Hole and Heizer 1969:59ff.). From other analytical perspectives, however, this facile, general definition is inadequate. For one thing, activities occur in systemic contexts and do not consistently result in remains deposited in archaeological contexts. Some kinds of activities had loci but did not result in the deposition of artifacts or residues into archaeological contexts. Other kinds of activities, for example, transporting goods or traveling, simply are not fixed to one location.

From a practical perspective, for problems of site discovery, the activity-oriented definition of site is not operational enough to be useful. When considering problems of discovery, sites are more properly defined operationally as the loci of archaeological materials and residue (Schiffer and Gumerman 1977: 183–184). Here, archaeological remains are divided into several categories referred to collectively as *site constituents*. Site constituents include, but are not necessarily limited to: artifacts, features, anthropic soil horizons, and human-generated anomalies of soil chemistry, resistivity, magnetism, or other soil characteristics. Several of these constituents are described and discussed in more detail below. The types, frequency, and intrasite spatial distribution of different constituents within a site strongly affect the likelihood of its detection.

Discovery itself requires only the detection of one or more site constituents. This is sufficient to suggest that a site might be present. The criteria that are used subsequently to determine whether a "site" actually exists (see Dancey 1981: 20–21) are immaterial to the prior issue of discovery. The important points of the preceding discussion for the perspective in this chapter are

(1) that archaeological sites are physical and chemical phenomena, (2) that there are different kinds of site constituents, and (3) that the abundance and spatial distribution of different constituents vary both among sites and within individual sites.

It is important to consider the extent to which different types of site constituents occur among archaeological sites when evaluating the effectiveness of various techniques for site discovery. If, for example, a technique will detect only a site constituent that is expected to occur in a small fraction of the sites within a study area, then that technique is hardly likely to be the best choice if a project goal is to obtain a sample of sites that represent the total variation among sites. On the other hand, if a project goal is to identify only sites with a constituent that is relatively rare, then a technique that will detect that constituent is ideal, even if it detects no others.

It is important to consider the abundance and spatial distribution of various constituents within sites when considering the effectiveness of the techniques for site discovery. A constituent that occurs in many sites, but in only small amounts or in very small areas of sites, is likely to require a discovery technique that can be applied economically at very close intervals within a study area in order to ensure the detection of the rare or highly clustered constituent. If no such technique is available, a constituent with these intrasite characteristics is not a good candidate to focus discovery efforts on, despite its common occurrence among the population of archaeological sites.

Despite the fundamental relationship between discovery, the intersite frequency of site constituents, and their intrasite abundance and distribution, archaeologists have not examined and described the occurrence of site constituents systematically. This is because archaeological site analysis aims mainly to interpret site contents and, structure culturally or behaviorally. It also reflects the traditional emphasis on the investigation of easily located sites, that is, obtrusive sites in areas where visibility is high and discovery was and is no problem. Recent concern among some archaeologists for the physical and chemical characteristics of archaeological sites indicates that this lacuna of archaeological information will begin to be filled in soon (Carr 1982; Nance 1980b, 1981; Rice *et al.* 1980; Scott *et al.* 1978; Stone 1981a, 1981b). The past lack of attention, however, means that there is no consolidated data base for reference regarding information about the intersite abundance or the intrasite frequency and distributions of site constituents in sites of various types, time periods, and different regions. Yet this sort of information would be extremely useful for determining the effectiveness of different techniques for discovering sites with particular frequencies and distributions of various constituents.

The following discussion about various site constituents, therefore, contains no empirically confirmed general statements. Lacking a comprehensive or core data-set for reference, examples of the abundance and distribution of different constituents are drawn from my experience and familiar sources rather than a more generally representative sample. The examples are not offered as "typical" sites; however, most sites contain one or more of the constituents discussed here. As will be noted instantly by historical archaeologists, the discussion and examples derive from my experience with and research interest in prehistoric remains. I hope that insights regarding historic-period remains also can be derived from this presentation but no one should infer that it is intended to do so directly.

Five of the most-common site constituents are considered in this chapter: (1) artifacts, (2) features (i.e., former facilities or parts of facilities), (3) anthropic soil horizons, (4) chemical anomalies, and (5) instrument anomalies, including magnetic, resistivity, and subsurface radar anomalies, as well as anomalies affecting surface vegetation or soil. These are what I perceive as the most commonly recognized and discussed constituents, not a comprehensive listing of all possible fractions of the archaeological record.

Artifact, Feature, and Anthropic Soil Horizon Distributions

The intrasite distributions of artifacts, features, and anthropic soil horizons are not isomorphic; nor are they invariably found, individually or as a group, at all sites. For this discussion, however, they are combined because the examples used here permit direct comparisons of their respective intrasite frequencies and distributions. Before proceeding, the terms must be defined. The term *artifacts* is used here to refer to the portable products and byproducts of human activities. Included are tools and manufacturing debris of stone (lithics), ceramics, wood, bone, antler, and other raw materials, along with fire-cracked rock and faunal and floral remains. Artifacts can be isolated or part of a dense cluster. They can be found within features and anthropic soil horizons, but it is the frequency and distribution of artifacts outside these other constituents that is of interest here. By *feature* is meant a sharply delimited concentration of organic matter, structural remains, soil discoloration, or a mixture of these and artifacts. Features typically are small relative to total site area; examples include trash or storage pits, hearths, house floors, building foundations, and postmolds. *Anthropic soil horizon*, on the other hand, refers to an extensive deposit that might be sharply or diffusely delimited. Such soil horizons typically result from deposition of large amounts of organic remains in a roughly delimited, relatively large (compared to features) area. They frequently have artifacts and features embedded in their matrices. Anthropic soil horizons sometimes are termed *middens*. A well-known example of such horizons is *shell middens*, dense deposits of shellfish and other remains found along some coasts and rivers. *Trash middens*, that is, dense, consolidated deposits of secondary refuse found in or adjacent to some sedentary settlement sites, are another frequently reported type of anthropic soil horizon. In other cases, such horizons are merely bands of distinct and anomalously colored soil in which sufficient organic material was deposited by human activities to alter the color of the natural soil profile. Anthropic horizons are the principal constituent used for the detection of deeply buried sites, as is discussed below.

For the comparisons in this section, the abundance or frequency of the individual types of constituents are measured by their average occurrence per excavation unit. The extent of the spatial distribution is measured by the number or percentage of excavation units in which the constituent occurs. The latter measure is not an ideal one for measuring the spatial arrangement of a constituent. Given the limited comparative data available, however, it is the measure that allows the most direct comparison of the extent of spatial distribution of the different constituents.

The difficulty of finding reports that include descriptions of the intrasite abundance and the spatial distribution of artifacts (as defined above), features, and anthropic soil horizons was surprising initially. Upon reflection, however, it is a logical expectation of the lack of attention by archaeologists to the strictly physical characteristics of sites and the lack of concern about discovery. Three examples are offered here, although even these require some extrapolation to derive comparative information about the intrasite abundance and horizontal distribution of artifacts, features, and anthropic soil horizons.

One source that includes sufficient data is the report on the Hatchery West site (Binford *et al.* 1970), an Archaic through Late Woodland village site in Illinois. The report describes the surface distribution of

several kinds of common artifacts—chert chippage, ceramic sherds, and fire-cracked rock—as well as the distribution of subplowzone features within a large area from which the plowzone was stripped mechanically. By focusing upon the area where plowzone stripping occurred, distributions of artifacts and features can be compared to one another directly. Apparently no anthropic soil horizon was found at Hatchery West, so this constituent is not included in the comparison. It is possible, however, to compare the abundance and spatial distribution of surface-collected artifacts, specifically ceramic sherds and chert chippage, with those of subplowzone features.

Ninety-six 6×6 m surface collection units were located within the area subsequently stripped. Judging from the artifact distribution maps in the report (Binford *et al.* 1970:5, Figure 2), 90% of the area was covered by a surface distribution of 1 to 5 ceramic sherds per 6×6 m collection unit (Table 4.1). Certainly sherd frequency per unit would have been higher and their spatial spread wider if the entire plowzone had been excavated and screened rather than only the surface artifacts collected. The surface distribution of chert chippage at a frequency of 10 or more per 36 m^2 at least partially covered 79% of the collection units; overall it covered approximately 59% of the stripped area (Binford *et al.* 1970: 10–11, Figures 3 and 4). As with the sherds, recovery of chert chippage from all of the plowzone surely would have increased the inferred frequency and spread of chert chippage.

None of the 6×6 m grid units were filled completely by features that occur in at least a part of 51 collection units, or 59% of the total number. These 51 units included many that contained only a small section of feature, and features commonly overlapped the boundary between two or more units. Features covered only about 15% of the subplowzone surface of the stripped area.

As the data are described in the report, it is not possible to derive the frequencies of ceramics or chert chippage for each 6×6 m unit, nor can the exact area covered by artifacts be estimated as it can for features. Despite this, the overall spatial distributions of artifacts can be described and clearly are much more widespread than that of the features at Hatchery West.

A second example, one that includes consideration of an anthropic soil horizon, comes from a survey and two excavations by Chapman (1977, 1978, 1981) in the Little Tennessee River Valley. Chapman conducted a survey to locate deeply buried sites, and discovered a large number of them. Among the sites he partially excavated after their discovery are the Bacon Bend and Iddins sites. The report on these sites (Chapman 1981) contains data that allow a direct comparison of the intrasite abundance and spatial distribution of artifacts, features, and anthropic soil horizons.

Chapman (1978:3) selected for excavation portions of sites where anthropic soil horizons were prominent, so these data are biased in their favor. Judging from the photographs and excavation wall profiles in the site reports, the anthropic horizons are spread widely throughout the excavated areas (Chapman 1981:9–11, 50–55). These excavated areas are only a part of each site area, however, as demonstrated by the trenching done to delimit the anthropic soil horizon at the Iddins site. At Iddins, the anthropic soil horizon referred to by Chapman as a *midden* was identified in Trenches 2, 4, 5, and 7, which are distributed over a linear distance of about 100 m (300 feet). Artifacts, on the other hand, seem to be distributed more widely. In each of the trenches at least a few artifacts or pieces of fire-cracked rock were found. Artifacts or fire-cracked rock were also found in other trenches on either side of the main group. The distances between the main group of trenches (2, 4, 5, 6, 7) and the outliers (1, 3) are substantial, 190 m (625 feet)

TABLE 4.1

Comparisons of Abundance and Spatial Distributions of Artifacts, Features, and Anthropogenic Soil Horizons

Site/reference	Artifacts	Features	Anthropogenic soil horizons
Hatchery West, plowzone stripped area (Binford, <i>et al.</i> 1970: Figs. 2 and 3, pp. 7–13).	<ol style="list-style-type: none"> 1. Ceramics (≥ 1 sherd/36 m²) cover 90% of the area. 2. Chert chippage (≥ 10 pieces/36 m²) occurs in 79% of the 6 × 6 m units, or approximately 59% of the area. 	<ol style="list-style-type: none"> 1. Occur in 53% of the 6 × 6 m units. 2. Cover 15% of the area 	None recorded
Bacon Bend Site (40MR25) Stratum 7 (Chapman 1981: Figs. 7 and 12, pp. 12–29).	<ol style="list-style-type: none"> 1. Occur in 94% of the 5 × 5' excavation units. 2. \bar{X} /unit = 61.^a 	<ol style="list-style-type: none"> 1. Occur in 61% of the 5 × 5' excavation units. 2. \bar{X} /unit = 1.1 	Widespread in the excavated area.
Iddins Site (40LD38) Stratum III Chapman 1981: Figs. 48, 57 and 59, pp. 48–60).	<ol style="list-style-type: none"> 1. Occur in 95% of the 5 × 5' excavation units. 2. \bar{X} /unit = 145.^a 	<ol style="list-style-type: none"> 1. Occur in 67% of the 5 × 5' excavation units 2. \bar{X} /unit = 1.4 	Widespread in the excavated area.

^a Average is for most frequent artifact type reported for site. Bacon Bend = "general excavation debitage"; Iddins = "bifacial thinning flakes > ¼ inch."

and 270 m (900 feet) respectively, and the continuous distribution of artifacts throughout the intervening areas is an inference that might not appeal to everyone. Even the spread of artifacts into part of this area, however, means that their spatial distribution is wider than that of the anthropic soil horizon. Furthermore, sites with artifacts but no anthropic soil horizons were not uncommon throughout the Little Tennessee survey area. In summarizing his results, Chapman (1978:3, 143) notes that many sites he discovered did

not include thick, definite anthropic soil horizons like those at Bacon Bend and Iddins, although artifacts were found.

The spread of artifacts, of course, differs from their frequency in any given area and they must occur frequently enough to be discovered. For the excavated portions of the Bacon Bend and Iddins sites, data are available to estimate the average frequency per 5×5 ft excavation unit for both artifacts and features ([Table 4.1](#)). Artifacts occur in about 30% more excavation units than features and are much more frequent per unit. Most features, of course, are much larger than most artifacts; however, it is likely that within individual excavation units artifacts are more widely distributed than features and cover more space than the feature(s) within the unit. The large number of artifacts per unit, unless they are tightly clustered, suggests a wider distribution than does the small number of features, most of which are circular with diameters of about 60 cm (2 feet) (Chapman 1981: Figures 12 and 59). Data about the specific locations of artifacts within the excavation units are unavailable to pursue this question further.

The frequencies and spatial distributions of artifacts and features from these two excavation areas probably is not representative of the entire site areas. The areas excavated were chosen because they seemed to have the densest distribution of organic and artifactual remains (Chapman 1981:3). Other sections of the sites, within a boundary drawn according to a low frequency of artifacts or features, would not have such frequent and dense remains.

A third example provides data from entire site areas. These data come from four sites investigated as part of the Cape Cod National Seashore Archeological Survey (McManamon 1981b, 1981c, 1982). Sites were examined by shovel tests (ca. 40 cm diameter) and small excavation units (50×50 cm to 150×150 cm). The tests and excavation units were distributed over the site areas, which were defined as the areas inside a 1-lithic-artifact-per-shovel-test contour line. A few of the tests and excavation units are adjacent to one another; most are spaced at 10 to 25 m intervals. The number of tests and units at the sites ranges from 34 to 86. The average frequencies of site constituents for tests and units in which they occur are given per $.25 \text{ m}^3$ so that excavations with different volumes can be compared directly ([Table 4.2](#)). Artifacts are represented directly by the remains of chipped stone, but some extrapolation is required to infer the frequency and distribution of features and anthropic soil horizons. Features are represented by the occurrence of dense remains of fire-cracked rock or of distinctly delimited anomalies of soil color, texture, or contents. Anthropic soil horizons are represented most frequently by dense shellfish remains, a relatively common, but not ubiquitous, type of anthropic soil horizon in coastal archaeological sites.

As in the other examples, artifacts are dispersed much more widely than either of the other constituents-in 79–82% of the excavations ([Table 4.2](#)). Features occur in 2 to 19% and anthropic soil horizons in 6 to 28%. In addition to occurring in less of the area of these sites, the variation in occurrence is far more pronounced in the latter two types of constituents.

TABLE 4.2**Relative Frequency of Occurrence of Artifacts, Features, and Anthropogenic Soil Horizons in Excavation Squares and Shovel Tests at Four Sites on Outer Cape Cod, Massachusetts**

Site (<i>N</i> units at site)	Chipped Stone	Dense Fire-Cracked Rock ^a	Dense Shellfish Remains ^a
19BN274 / 339 (70)	$\frac{\% \text{ units}}{\bar{x} \text{ per unit}}$ 79% 30/.25 m ³	17% 2258g/.25 m ³	17% 973g/.25 m ³
19BN341 (86)	$\frac{\% \text{ units}}{\bar{x} \text{ per unit}}$ 81% 104/.25 m ³	19% 305g/.25 m ³	28% 439g/.25 m ³
19BN273 / 275 (53)	$\frac{\% \text{ units}}{\bar{x} \text{ per unit}}$ 79% 29/.25 m ³	2% 461g/.25 m ³	17% 412g/.25 m ³
19BN340 (34)	$\frac{\% \text{ units}}{\bar{x} \text{ per unit}}$ 82% 24/.25 m ³	6% 445g/.25 m ³	6% 319g/.25 m ³

^a Dense deposits are those of 100 g or more. The percentages also include units that have features or anthropogenic soil horizons without dense fire-cracked rock or dense shellfish remains, respectively.

These three examples support the impression of many archaeologists about the relative intrasite abundance and spatial distribution of these three site constituents. Artifacts commonly are the most widespread and abundant of site constituents. Features and anthropogenic soil horizons do not commonly approach the extended spatial distribution of artifacts and in some cases might not even exist in a site area or large portions of it.

Regarding the intersite abundance of these three types of site constituents, it might be sufficient to note that it is easy to conceive of archaeological sites that contain neither features nor anthropogenic soil horizons, but not so easy to imagine one without artifacts. This is so for two reasons. First, artifacts are made and used in more, and more widely distributed, activities than the other two constituents. In general, features result from activities that involve the construction, maintenance, and use of facilities such as storage pits, hearths, and structures. Anthropogenic soil horizons result from the relatively large-scale processing or dumping of organic materials. Both of these kinds of general activities are likely also to involve artifacts, some of which frequently end up in archaeological contexts along with the remains of the facility; that is, the feature(s) or the organic remains (the anthropogenic soil horizon). In addition, artifacts that are used in systemic contexts independent of facilities or large amounts of organic materials also are deposited in archaeological contexts through discard, loss, or abandonment.

The second reason that artifacts are more frequent and widespread in the archaeological record than are features and anthropogenic soil horizons is their relative durability. Lithic artifacts, for example, can persist for millions of years, withstanding weathering by natural agents and postdeposition disruptions by fauna or human agents. Not all types of artifacts are as durable as lithics, of course. Ceramics, metal, and bone

artifacts, for example, break down rapidly in some depositional environments. In general, however, artifacts in archaeological contexts are less likely to be destroyed by natural soil processes or unnatural disruption (e.g., agricultural plowing) than either features or anthropic soil horizons.

In summary, all other things equal, techniques that detect artifacts will be more effective at discovery than those that detect only features or anthropic soil horizons. This general point is elaborated in a later section and consideration is given to the levels of intrasite artifact frequencies and spread that facilitate site discovery.

Chemical and Instrument Site Constituents

Like the first three constituents described, the last two are grouped for discussion, but for a different reason. It is argued here that these types of site constituents are of limited value for site discovery for at least one out of the following three reasons: (1) they have a low frequency among sites, (2) they are infrequent and/or highly clustered within sites, or (3) their detection requires extensive, detailed background information that is difficult to obtain for large study areas. On the other hand, for intrasite examination following discovery, the investigation of these types of constituents can be extremely useful both for planning excavations and behavioral interpretation (e.g., see Tite 1972; Carr 1977, 1982).

As with the previous section, this one is not a comprehensive description of the characteristics of chemical and instrument site constituents. A detailed presentation of the genesis, development, and interpretation of such constituents requires substantially more space than is available here, as demonstrated by Carr's (1982) thorough and illuminating examination of the chemical and resistivity constituents at the Crane site. Here my aim is merely to draw upon the detailed work that has been done and to argue for the position outlined above.

Chemical anomalies within sites usually are caused by the deposition of organic waste in the soil through the disposal of garbage, urination, and excretion (Cook and Heizer 1965:12–14; Provan 1971:39). Carr (1982:449–467) provides very detailed estimates of the proportions of various chemical elements in different kinds of refuse material. A variety of chemical elements within archaeological sites have been investigated, including calcium, carbon, magnesium, nitrogen, potassium, sodium, sulfur, and especially phosphorus in the form of soil phosphate (e.g., Carr 1982; Cook and Heizer 1965; Eidt 1973, 1977; Heidenreich and Konrad 1973; Heidenreich and Navratil 1973; Proudfoot 1976; Provan 1971; Valentine *et al.* 1980; Woods 1977).

Cook and Heizer's (1965:29–61) analysis of the chemical constituents of two groups of sites in California contains the largest number of archaeological sites (73) compared chemically. A recent but less-extensive study of Eidt (1977:1330–1332) compares a smaller number of sites for soil phosphate fractions. The sites analyzed by Cook and Heizer were divided by them into two groups. The first group included 48 sites from northern California. One sample from each of these was analyzed for percentage of total phosphorus. The results were compared to the percentage of total phosphorus expected in natural soil, based upon 193 samples from locations in central and northern California.

Cook and Heizer (1965:40) considered values greater than the mean for the natural soils by two standard errors to indicate significant cultural modification of the site soil chemistry. They found significantly high scores in all but 8 of the 48 sites. Of the 8 with low scores, they dismiss 2 as from sterile portions of the

sites and the others as from sites that were not substantially occupied (e.g., a temporary camp or cemeteries [1965:41–44]).

The first series data, however, have several serious problems. First, only a single sample is available from each site. Usually a single sample is insufficient for characterizing the abundance and distribution of phosphorus throughout the site. Proudfoot (1976:104–109) provides a thorough discussion and examples of soil phosphate variation and sampling concerns. Second, because the archaeological site soil tests are single values rather than averages, the appropriate comparison would have been with a score two standard *deviations* from the mean value for natural soil instead of the two standard *errors* of the mean value used. The standard deviation describes the spread of actual scores, such as those available from each archaeological site. The standard error of the mean is an estimate of the sampling distribution of the mean and usually is substantially smaller than the standard deviation. Third, the archaeological site samples are biased toward high phosphorus content because most of them "contained actual site midden, or matrix" (1965:40). Finally, the in-site values are compared with average natural soil values for a large area rather than with samples from natural soils adjacent to the site, making it impossible to know how frequently naturally high phosphorus in the parent material of the site soil caused anomalously high scores in the site areas. The large percentage of sites with significantly high scores, therefore, is not necessarily an indication that such scores are abundant among all sites.

Data from the second series of sites examined by Cook and Heizer are more detailed and avoid these problems. Scores for a series of tests are given and areas adjacent to sites were tested for comparisons. For this example a separate analysis of two other California sites by Cook and Heizer (1965:29–39), which provides similar data, is included with the second series of sites. Like the first, the second series of sites is from the northern or central parts of the state. From among this group of 15, the results of chemical tests from six are described in enough detail for sample statistics (\bar{X} and s) to be derived, and in four cases for the same statistics to be generated for adjacent off-site areas (Table 4.3).

Table 4.3

Variation in Chemical Constituents among Six California Sites and Adjacent Off-Site Areas^a

Site (N samples)	Carbon (%)				Nitrogen (%)				Phosphorus (%)				Calcium (%)			
	\bar{X}	s	-2s	+2s	\bar{X}	s	-2s	+2s	\bar{X}	s	-2s	+2s	\bar{X}	s	-2s	+2s
NAP-1 (3)	5.61	.70	4.21	–	.352	.066	.220	–	1.12	.03	1.06	–	14.80	1.53	11.74	–
NAP-1, <i>off site</i> (4)	4.60	2.60	–	10.32	.239	.105	–	.449	.19	.19	–	.57	.16	.07	–	.30
NAP-131 (15)	1.80	.81	.18	–	.128	.044	.04	–	.12	.04	.08	–	.15	.06	.03	–
NAP-131, <i>off site</i> (2)	1.16	0	–	1.16	.100	.012	–	.124	.08	.01	–	.10	.06	0	–	.06
<i>Elam</i> (13)	33.62	9.35	14.92	–	.741	.195	.351	–	3.36	1.17	1.02	–	9.10	4.32	.46	–
<i>Elam, off site</i> (4)	*	*	–	*	.703	.130	–	.963	.24	.11	–	.46	1.54	.85	–	3.24
<i>Haki</i> (11)	11.80	2.56	6.68	–	.319	*	*	–	.136	.050	.036	–	.421	.150	.121	–
<i>Haki, off site</i> (5)	8.75	6.48	–	21.71	.182	.107	–	.396	.114	.035	–	.184	1.017	.590	–	2.197
<i>Alnuiki</i> (9)	11.84	7.35	0	–	.205	.057	.91	–	.107	.04	.99	–	.189	.160	.157	–
<i>Alnuiki, off site</i> (8)	4.61	*	–	*	.121	*	–	*	.078	*	–	*	.118	*	–	*
<i>Kicil</i> (9)	11.58	8.52	0	–	.217	.085	.47	–	.116	.059	0	–	.493	.455	0	–
<i>Kicil, off site</i> (6)	9.99	*	–	*	.253	*	–	*	.080	*	–	*	.263	*	–	*

^a Data from Cook and Heizer (1965:29–61); *, value not available.

Analysis of the four cases for which the mean and standard deviation for site and off-site tests are available follows in more detail below. Before proceeding, however, it is interesting to examine more closely the range of mean values for different elements among the sites and off-site areas (Table 4.4). The site and off-site ranges partially overlap for all elements; for nitrogen and carbon they are practically the same. Carbon shows a wide range of values both on and off sites, as does calcium. These figures point out the need for detailed background information on the natural soil level of chemical elements in any area where chemical testing is used, and for careful, extensive sampling as part of such a testing program (Carr 1982; Proudfoot 1976). The California data demonstrate that no widely applicable single value exists for any of these elements that conclusively indicates the presence or absence of a site.

The comparison of specific sites versus off-site areas sheds further light on the likelihood that unnaturally high chemical values will be found within site areas. Cook and Heizer included individual test scores for four off-site areas. They do not provide a general statement about how they drew boundaries separating the site from its natural soil setting. However, the specific descriptions they provide for each of the second series of sites indicate that they used observed surface distributions of artifacts and middens, historical and ethnographic accounts, or, for some sites, partially buried but visible structural remains. Using the same statistics generated from the site and off-site test scores, Table 4.5a shows the percentages of scores within sites that are below the upper 95% confidence interval for natural soil scores. Within some sites some elements have substantial percentages of low scores. Examining the lower end of the expected distribution of scores for site areas (Table 4.5b), it is clear that many of the actual scores from off-site areas overlap with it. In other words, whereas some sites contain sections where element scores are anomalously high, other substantial sections have scores not significantly different (at least at the 95% confidence level) from the scores found in adjacent off-site areas.

TABLE 4.4

Range of Mean Values for Percentage of Chemical Elements among Six California Sites and Adjacent Off-Site Areas ^a

Elements	Sites	Off-site areas
Carbon	1.80–11.84	1.16–9.99
Nitrogen	.128–741	.100–703
Phosphorus	.12–3.36	.078–24
Calcium	.15–14.80	.06–1.54

^a Data from Cook and Heizer (1965:29–61).

TABLE 4.5

Chemical Constituent Scores within Four California Sites and in Adjacent Off-Site Areas^a

Site (<i>N</i> samples)	Carbon (%)	Nitrogen (%)	Phosphorus (%)	Calcium (%)
Low scores within sites (%) ^b				
NAP-1 (3)	100	100	0	0
NAP-13 (15)	6	67	33	0
Elam (13)	*	92	0	8
Haki (11)	100	91	91	100
High scores in off-site areas (%) ^c				

NAP-1 (4)	50	75	0	0
NAP-131 (2)	100	100	50	100
Elam (4)	*	100	100	100
Haki (5)	60	*	100	100

^a Data from Cook and Heizer (1965). *, value not available.

^b Scores within sites less than two standard deviations above the mean for the adjacent off site tests.

^c Scores in off-site areas less than two standard deviations below the mean for the adjacent site.

Similar results come from a detailed chemical survey of the Robitaille site (a Huron village in Ontario) and the adjacent off-site area (Table 4.6). The reports about this site (Heidenreich and Konrad 1973; Heidenreich and Navratil 1973) distinguish only the village area of the site rather than a site boundary. Some of the area outside the inferred village area undoubtedly contains trash deposits, chemical anomalies, and so forth associated with the village, and is properly considered part of the site area. The distinction in Table 4.6 between village and nonvillage areas, therefore, is not strictly a site-off-site dichotomy. Despite this, the variation in scores (Table 4.6) suggests the discontinuous distribution of anomalously high chemical scores inside sites in which they occur.

TABLE 4.6

Chemical Constituent Values (%) at the Robitaille Site, Ontario, Canada^a

Element	Village area (<i>N</i> = 42 samples)		Outside village area (<i>N</i> = 98 samples)	
	High scores	Low scores	High scores	Low scores
Phosphorus	69	31	23	77
Magnesium	21	79	3	97
Calcium	83	17	17	83

^a Data from Heidenreich and Navratil (1973) and Heidenreich and Konrad (1973). All samples with scores above the 95% confidence interval for natural soils are considered high. Those with scores at or below this value are counted as low.

A third example from a multicomponent site in Northern Ireland (Proudfoot 1976) shows a similar pattern. There the analysis of phosphate content in over 80 samples showed wide ranges of values across the site area. Proudfoot (1976:110) in fact interpreted many of the scores as the result of natural conditions, such as natural phosphate-rich igneous rocks and soil development. He does note, however, that at least some of the Neolithic pits seem to have been partially filled with phosphate-rich material from human activities.

The first two examples of intrasite scores and site–off-site comparisons used the 95% confidence limits of the inferred distributions. There is nothing magical about this level of significance (Cowgill 1977). It is used here because Cook and Heizer and Heidenreich, Konrad, and Navratil, from whose work most of the examples or data are drawn, use the 95% limit in one way or another. Obviously a less-stringent confidence limit would alter the percentages in Tables 4.5a, 4.5b, and 4.6.

From these examples three generalizations relevant to site discovery can be derived about the chemical constituents of archaeological sites. First, a hefty percentage of all sites might contain no anomalous chemical constituents. In their most-detailed analysis of California sites (the second group of sites discussed above), Cook and Heizer (1965:40–61) found that 38% (5/13) showed no significant deviation from the chemical characteristics of adjacent natural soils.

Second, these examples of the intersite abundance of significantly high anomalous scores suggest that it varies widely among sites and among elements within sites. The mere occurrence of a significantly high score within a site in no way ensures that anomalously high scores will be obtained from all of the site area. These points are confirmed by a very detailed example and analysis of intersite variation among chemical site constituents by Carr (1982:387–551).

Finally, it ought to be clear that the accurate identification of anomalously high chemical scores that were generated by prehistoric human behavior requires very detailed and extensive information from both off-site and site areas. To emphasize this, consider the Crane site, a 2.6 ha (6.5 acre) multicomponent Woodland site in Illinois. Carr (1982:467) notes the large number of distinct spatial strata into which the site area could be divided based upon differences in the texture and chemical composition of the natural soil parent material, variation in the degree of soil profile development, and the chemical effects of differential historic period land-use. For accurate interpretation of soil chemical test scores, background information about these natural and historic phenomena should be available. Although Carr (1982) skillfully demonstrates that this kind and detail of background information can be assembled, organized, and interpreted within a relatively small area—for example, the Crane site—a similar level of analysis over wider study areas would be extremely difficult.

Site constituents that are detectable using various instrument techniques, such as resistivity, subsurface radar, and remote sensing, are considered as a group for two reasons. First, the anthropic anomalies that the different instruments detect are caused by the same general kind of archaeological remains. These site constituents are anomalous localized patterns of electric resistance, magnetism, radar reflection, surface vegetation—for example, crop marks or soil reflection. The clearest anomalies are caused by remains that distinctly and strongly differ in material and texture from the surrounding soil matrix; examples include filled ditches, walls, roads, kilns, pits, and house floors. Second, the overall frequency of such constituents as well as their intrasite abundance and distribution are expected to be similar because the anomalous patterns that are the constituents are caused by similar kinds of remains.

Unfortunately, except for two examples regarding remotely sensed constituents, I have not uncovered data amenable to multisite comparisons. The two examples discussed below, however, do give a notion of the frequency of these types of site constituents among all sites.

For a recent survey of Ninety-Six National Historic site, located in the meadows and woods of the South Carolina piedmont, documentary research and archaeological fieldwork identified 22 sites within the approximately 200 ha (500-acre) study area (Ehrenhard and Wills 1980). Of these, five

(23%) were detected through aerial photograph interpretation using black-and-white and infrared images plus a photogrammetric topographic map with a 2-foot contour interval (Table 4.7).

Within the five sites that were identified by remotely sensed constituents, the remains generating the anomalies were linear or rectangular, usually the remains of a historic period structure or structural feature. All five sites were in areas cleared of most vegetation (Ehrenhard and Wills 1980:264–285). Table 4.7 shows that recent disturbances were the most easily detected with fewer than half of the historic and none of the prehistoric sites detected. The undetected sites either lacked the necessary constituents to cause the recognizable anomalies or were in locations lacking the visibility requirements of black-and-white and infrared imagery.

The second example demonstrates the same requirement of structural archaeological remains and low-lying vegetation or a lack of vegetation for the successful identification of archaeological sites, in this instance using color infrared aerial photographs in the Tehuacan Valley in Mexico (Gumerman and Neely 1972). The types of sites visible on the imagery, either directly by an anomalous reflectance pattern or indirectly through crop marks included platform mounds, canals, subsurface foundations, former water and soil control ditches or dams, courtyards, plaza areas, and ball courts. On the other hand, small sites without the remains of structures were not detected by the imagery analysis (Gumerman and Neely 1972:522–523).

TABLE 4.7

Detection of Known Sites at Ninety-Six National Historic Site, South Carolina^a

	Prehistoric	Historic	Recent historic
Known sites (22)	8 (36)	9 (41)	5 (23)
Anomalies caused by sites and observed (5)	0 (0)	3 (60)	2 (40)

^a Data from Ehrenhard and Willis (1980). Values in parentheses are percentages.

Vegetation patterns also strongly affected the ability to detect the full range of site types. In most of the Tehuacan study area the ground surface was "almost barren limestone or travertine with little or no soil cover...the dominant vegetation comprises short grasses" (Gumerman and Neely 1972:525). Forest canopy vegetation, however, obscured all sites in the areas where it occurred. The forest canopy in this instance was a "thorn-forest" with a canopy 1–2 m above the surface. Although the canopy was not uniformly dense, it did effectively conceal even sites with otherwise detectable constituents so that they could not be distinguished from natural features (Gumerman and Neely 1972:526).

These briefly described examples indicate that anomalous patterns of soil reflection or vegetation are characteristic of some kinds of archaeological sites; more precisely, of some portions of some sites. Typically, former structures or structural facilities, for example, ditches and dams, cause these anomalies. This type of site constituent will exist among archaeological sites to the extent that such distinct and different remains are close enough to the surface to affect soil or vegetation. Beyond the question of how frequently this constituent occurs, its detection requires stringent conditions of visibility. Obtrusiveness, in this instance, is affected strongly by visibility. Low-lying vegetation, such as particular grasses or crops, is essential for crop marks to be detected and

the absence of vegetation is a prerequisite for soil mark detection. Forests or shrub cover ordinarily prevent the detection of either.

Considering the relative rarity of the remains that cause them, most instrument site constituents seem unlikely to be widespread or abundant enough in the archaeological record to be the targets of *general* site discovery surveys. Readers will recognize that these types of constituents have been considered here superficially at best. This is so because the focus of this chapter is upon the discovery of sites, especially sites within which the remains necessary to cause instrument site constituents are rare. The next section identifies a variety of logistical constraints on instrument techniques that, like the points brought out here, argue for their use in intrasite rather than discovery applications.

At the beginning of this section on site constituents I argued that archaeologists should pay more attention to the physical and chemical characteristics of archaeological sites, and that the evaluation of discovery techniques required this kind of a perspective. The information about site constituents presented here and conclusions derived from it are based upon a strictly inductive approach. I have looked at specific examples and drawn general conclusions based upon them. To a large extent this approach was born of expediency.

A different, more difficult, but ultimately more useful approach to describing site constituents could be developed using a deductive framework; that is, by beginning with a series of activities that one expected to occur and predicting the types and distributions of site constituents that would be generated by them. This approach holds the promise of great progress for the evaluation of discovery techniques as it already has demonstrated its usefulness in methodological and behavioral analysis applications (Carr 1982; Cook 1976; Schiffer 1975).

TECHNIQUES FOR DISCOVERING SITES

A goal of this chapter is to identify the advantages and disadvantages of different techniques for site discovery, not to select one technique that will solve all site-discovery problems. In practice, several techniques often are joined in concert as parts of a single investigation. Different techniques are appropriate, for example, during various parts of a multistage sampling design, or in parts of an investigation area that present different discovery problems because of variation in soil aggradation, vegetation, access, or other conditions.

Furthermore, the main intent of this chapter is to consider the techniques appropriate to discover unobtrusive sites in places where visibility is poor. Therefore, not every discovery technique used by archaeologists is mentioned, and not all those mentioned are discussed in equal detail. Techniques useful only where visibility is good, or only for the discovery, or examination of relatively obtrusive sites, are not described or evaluated comprehensively. Situations for which such techniques are useful are mentioned briefly.

Surface Inspection

The most commonly employed discovery technique is surface inspection of lightly vegetated areas, eroding soil profiles, and plowed fields. Surface inspection has been applied with a wide range of approaches from opportunistic and spotty checks to very careful, intensive inspection of all (or an explicitly defined sample) of a study area. In the colorful terminology of House and Schiffer (1975:40), the approaches have ranged, with increasing intensity of inspection and, not surprisingly, greater numbers of site discoveries, from "whistle stop" to "hunt-and-peck" to "gladhand" to "gumshoe."

Surface inspection is a relatively quick and inexpensive discovery technique that is effective under two conditions. First, at least a portion of the archaeological sites of interest must be on the surface. Sites that were once buried but have been brought to the surface by plowing or erosion are included among these. The second condition is that the ground surface be cleared enough for sites' contents to be recognized visually. These conditions are met in large expanses of arid, lightly vegetated parts of the world. There, surface inspection, if intensive and rigorously applied, probably is effective for discovering most, though not all, sites (Hirth 1978; Judge 1981; Kirkby and Kirkby 1976:241–246; Schiffer and Gumerman 1977:214–215; Tolstoy and Fish 1975). In many regions, however, soil aggradation, natural disturbances within soil profiles (Wood and Johnson 1978), and vegetation have buried or obscured archaeological remains. Where this has occurred, sites without structural remains at or near the surface are very unobtrusive and difficult to discover. In these contexts, if surface inspection is the discovery technique, its effectiveness is limited to such windows of visibility as eroding shorelines, wind blowouts, roadway cuts, and plowed fields; and only those sites being eroded or within reach of the plow are susceptible to detection.

Where extensive modern agriculture and seasonal plowing occur, such as the American Midwest, surface inspection remains the most common discovery technique. Even with plowing, however, the problem of poor visibility sometimes remains, caused by the adhesion of soil to artifacts, making them difficult to see. Careful scheduling of surface inspections to take advantage of low amounts of ground cover, recent plowing, and recent heavy natural precipitation that washes soil off artifacts can reduce this concern but not eliminate it (Ammerman and Feldman 1978; Hirth 1978:130; Roper 1979:21–23). Although probably not preventing the discovery of some sites, this visibility problem is likely to cause a bias toward the discovery of sites with large numbers and dense concentrations of artifacts or highly obtrusive remains. The discovery of shell middens in coastal areas provides an example. In Cape Cod National Seashore, Massachusetts, the estimated frequency per acre of shell middens based upon an intensive probability sample drawn using a rigorous subsurface testing technique is similar to the frequency per acre based upon all previously known and reported prehistoric sites, most of which are shell middens. Based upon the intensive probability sample, however, the estimated frequency per acre for *all* prehistoric sites is 3–5 times the estimated shell-midden frequency (McManamon 1981b, 1981c). The previously known sites were reported over the years by avocational archaeologists who discovered them haphazardly in eroded cliffs, plowed fields, or construction areas. The collectors were not searching intensively or testing for subsurface remains and the most obtrusive remains, that is, shell middens, in locations where visibility was good were the ones detected.

A number of archaeologists have tried to improve visibility in regions with dense plant cover so that surface inspection could be used as a primary discovery technique. One method is to plow areas not currently cultivated (Binford *et al.* 1970; Davis 1980; Ives and Evans 1980; Keel 1976; Kimball 1980; Snethkamp 1976; Trubowitz 1981). Purposeful plowing markedly increases the amount of surface area that can be inspected; however, the difficulty of artifact visibility if the plowing is not followed by heavy precipitation also must be considered and the plowing and surface collecting scheduled accordingly. Plowing can present a variety of logistical problems as well (Trubowitz 1981). Forests are too dense for use of plows. Thick shrubbery or brush must be cleared before a plow can be used (Davis 1980; Kimball 1980). Where land parcels are small, and especially where they are used residentially, obtaining permission to plow is likely to be difficult or even impossible.

Archaeologists have utilized a variety of other means of increasing surface visibility by removing surface cover. Techniques used include raking or blowing away leaf litter (Bergman 1980; Forney 1980; Lafferty 1979, personal communication 1982; Otinger *et al.* 1982; Scott *et al.* 1978; Taylor

et al. 1980) and the use of heavy equipment, specifically a small bulldozer, to clear surface vegetation (Lafferty 1979). Although possibly appropriate to overcome some discovery problems, these additional techniques of increasing surface visibility have a major drawback. They result in the inspection of only the soil surface rather than a volume of soil. This differs from plowing, which draws artifacts from throughout the soil volume. Wood and Johnson (1978), using work by Darwin (1881), Atkinson (1957), and others, have described in some detail how in many areas natural soil movement processes bury archaeological remains deposited originally on the surface (see also Lewarch and O'Brien 1981:299–311). Hughes and Lampert (1977) argue that in loose sandy soils human treading around an occupations or activity areas has buried remains deposited on the surface. Therefore, surface vegetation clearing, even where geomorphic soil aggradation has not occurred, might not reach far enough beneath the modern surface to scratch up and detect archaeological sites.

Discovery techniques that aim to increase surface visibility can be effective. They are relatively inexpensive and will be useful under the following three conditions. First, the sites of interest must be detectable visually on or near the surface once the vegetation is removed or the soil plowed. This condition applies to all the techniques mentioned above whereas the last two conditions mainly relate to the equipment techniques, plowing, and other heavy machine clearing. The second condition regards natural constraints; vegetation must not be too dense or substantial, for example, and topography not too steep or irregular for equipment access and performance. Finally, legal access to the investigation area must be obtainable. This might be particularly difficult for equipment clearing, which is unlikely to be acceptable to landowners in developed commercial, residential, or recreational areas.

Subsurface Techniques for Site Discovery

Other techniques increasingly are being developed and applied where surface inspection has been recognized as ineffective. The techniques described below are termed *subsurface* because each detects one or more kinds of subsurface anomaly. For ease of discussion and evaluation, the techniques are divided into four general classes: instrument techniques, chemical tests, remote sensing techniques, and subsurface probes. The first two classes are described rather briefly because their principal use has been intrasite examination rather than site discovery. Considering the kinds of site constituents these two types of techniques detect, the detailed background data required for accurate interpretation of their results, and their logistical requirements, they are likely to remain useful primarily for intrasite investigations. The third class of techniques—remote sensing techniques—have proved to be effective for the discovery of sites with certain kinds of constituents when such sites are located in areas where visibility is good. Although these conditions limit the instances for which remote sensing is an effective discovery technique, when such conditions are met by a project's goals and the study area, remote sensing techniques will prove quick, accurate, and relatively inexpensive.

None of these first three types of techniques is described or evaluated comprehensively in this chapter; interested readers should consult specialist references for complete details. The description and evaluation in this chapter are limited to the consideration of the techniques as tools for site discovery. In keeping with the emphasis of the earlier sections on the discovery of unobtrusive sites in environments with poor visibility, subsurface probes—the final technique considered here—are described and evaluated comprehensively. Before discussing the probes, however, the other techniques are dealt with.

Instruments

The major instrument techniques used in archaeological field investigations have been magnetometry, resistivity, and subsurface radar. Magnetometers detect slight variations in the earth's magnetic field. Some kinds of buried archaeological features, especially pits and structures that have been burned, and hearths, produce such variations (Aitken 1970:681; Steponaitis and Brain 1976:455; Tite 1972:7–57). Magnetometers have been used since the late 1950s "for specific problems in connection with particular excavations" (Scollar 1969:77; see also examples in Aitken 1970; Breiner 1965; Leehan and Hackenberger 1976; Tite 1972:43–52). Given appropriate soil and magnetic background conditions they can be very successful, such as in an examination of sites partially buried by a sand dune at Oraibi Wash in Arizona (Rice *et al.* 1980:7) where a proton magnetometer detected and delimited areas that contained large numbers of hearths, pits, and structures. Additional examples of the kinds of subsurface features detectable are prehistoric stockade ditches (Black and Johnston 1962; Johnston 1964:128) and large storage pits (Gramley 1970). Clark (1975) reports the use in England of portable magnetometers for surveying relatively large areas, such as rights-of-way for proposed highways. He notes their successful detection of pits, hearths, ditches, and kilns.

Although they obviously can detect some kinds of features or anthropic soil horizons successfully and are relatively portable, wide-scale use of magnetometry for site discovery is unlikely to be effective for three reasons. First, the large, distinct anomalies they detect are relatively rare in the archaeological record. Large, distinct features or anthropic soil horizons seem to be relatively infrequent and spatially clustered constituents of sites in which they occur and they are expected to be absent in many other sites. Second, magnetometers are hindered or even made useless by substantial magnetic background such as is common within most modern developed areas. Third, natural magnetic properties of some soils or small variations in topography, soil horizon depths, and surface geological anomalies also can mask the magnetic contrast of otherwise detectable archaeological features unless the raw magnetic readings are filtered through sophisticated statistical computerized procedures to eliminate the natural magnetic noise (Scollar 1969). Thus, substantial amounts of information about the natural magnetic background are required. These detailed data can be collected for a site area or a portion of a site, but usually it is impossible to obtain the necessary data from an entire large study area.

Resistivity surveying measures the resistance to an electric current of soil and possible archaeological anomalies embedded in the soil matrix (Clark 1970; Tite 1972:7–57). Typically, large distinct features and anthropic soil horizons that differ substantially in consistency from the surrounding soil matrix can be detected as either anomalously high or low resistivity scores. Carr (1977:162; 1982:1–45) refers to dozens of American or European examples of the successful detection of individual abode, masonry, or hollow subsurface remains using resistivity. As with magnetometry, the focus of resistivity testing has been intrasite, and mainly the detection of individual features such as trenches, walls, house depressions, and large distinct filled pits (e.g., Clark 1970:696; Ford 1964; Ford and Keslin 1969; Goodman 1971; Klasner and Calengas 1981). Overall intrasite structure also can be detected using resistivity even in sites where features are small and earthen, if appropriate statistical procedures are applied (Carr 1977, 1982; Lieth *et al.* 1976).

Reservations similar to those regarding the applicability of magnetometry for site discovery can be raised for resistivity surveying. It detects a range of archaeological site constituents similar to that for magnetometry, thus having similar limitations for site discovery. In addition, a series of potential logistical problems make resistivity surveying undesirable for site discovery, or even for intrasite investigations, in areas with stony soil or dense vegetation. The probes through which the electric charge is sent and resistance to it detected must be inserted into the soil in a careful alignment. These requirements can be deterred by stony soil or dense vegetation. Also, as with

magnetometry, the collection and interpretation of natural background data is important but time-consuming in large survey areas.

Ground-penetrating radar is a technique with a short history of archaeological applications. Developed for geologic and engineering studies (e.g., Morey 1974), it has been applied by archaeologists in a variety of contexts including prehistoric (Roberts 1981a, 1981b; Vickers and Dolphin 1975; Vickers *et al.* 1976) and historic period sites (Kenyon and Bevan 1977; Parrington 1979:198–199; Weston Geophysical 1980). Ground-penetrating radar detects subsurface discontinuities as echoes of radar pulses that it transmits. The characteristics of the echo allow the determination not only of anomaly presence but of its depth, shape, and position in the soil profile. Soil characteristics, such as moisture content, can affect radar readings strongly, so detailed soils data are required for accurate interpretation (see Roberts 1981a, 1981b). Like resistivity, substantial and distinct features or anthropic soil horizons are the most likely to be detected by ground-penetrating radar. The radar equipment usually is housed in a small, low cart that is rolled over the area investigated. The area must be relatively smooth and without vegetation or with only low grassy cover for the cart to move freely. Problems similar to those outlined for the other two techniques apply for subsurface radar as well. In addition, subsurface radar equipment is much more expensive to purchase or lease than equipment for magnetometry or resistivity survey.

In summary, these three instrument techniques are likely to remain primarily as intrasite examination techniques. In sites with the appropriate constituents, one or more of these techniques can be very effective and efficient for the exploration of site structure or the location of areas for excavation. Their use for site discovery, however, would require three rare and stringent conditions: (1) that the sites sought contain substantial and distinct features or anthropic soil horizons; (2) that the area to be investigated be small with regular topography, a soil type compatible with the technique, and blanketed by only a low grassy ground cover, and (3) that the necessary expertise be available to conduct appropriate data-filtering techniques, collect the necessary background data, and interpret the resultant scores. In most cases, the kinds of sites for which these instrument techniques are useful can be discovered using quicker, less-expensive techniques with fewer logistical constraints. Once they are discovered, far more detailed investigation of their structure and contents using one or more of the instruments can be done effectively and efficiently within the site areas.

Chemical Tests

The earlier section on chemical anomalies within site areas indicated the substantial use of chemical tests for intrasite investigations to determine site structure, prehistoric activities, and the best locations for large excavations (Ahler 1973; Carr 1982; Cook and Heizer 1965; Eidt 1977; F. Goodyear 1971:202–222; Heidenreich and Konrad 1973; Heidenreich and Navratil 1973; Limbrey 1975:326–330; Overstreet 1974; Proudfoot 1977; Provan 1971; Valentine *et al.* 1980). Among the elements used for these analyses, phosphorus in the form of fixed phosphate compounds has been especially and most widely used. Whereas the other elements have been limited to intrasite investigations, phosphate testing has had a rather long history of use for site discovery as well. In northwestern Europe, Arrhenius in the 1930s and later Lorch used it as a means of discovery as well as to identify areas within sites for excavation (see bibliography in Provan 1971; Sjoberg 1976:447). More recent attempts to use this technique for site discovery have occurred (Eidt 1973, 1977; Provan 1971:44–46; Sjoberg 1976). Eidt's (1973) first article describing a simple rapid field technique for the qualitative or semiquantitative estimation of phosphate content seems to have provoked several of the recent attempts to use the technique for

discovery as well as intrasite studies. Eidt himself (1977), however, recognized the uncertainty and limitations of the rapid field technique. Phosphate intensities could not be compared rigorously due to uncertainty about the effects of sample size, unequal extraction of phosphate types, and other conditions under which the sample was collected and analyzed (Eidt 1977:1329). Furthermore, the rapid technique could not distinguish between high scores resulting from large amounts of naturally occurring phosphates and those derived from culturally deposited phosphorus (Eidt 1977:1329).

More quantitative analytic techniques have been applied recently (Carr 1982; Eidt 1977; Hassan 1981; Sjoberg 1976). These increase the amount of time required to analyze each sample, but they permit more rigorous comparison among the samples and more definite interpretations of the scores. The new analytic techniques, however, are not necessarily intended for discovery studies. Eidt (1977:1332) summarizes his article describing the new analysis by proposing a two-part method for chemical examination of archaeological sites. The initial part would be the old "rapid qualitative field test" for locating sites with a second stage of quantitative analysis to verify and analyze further if a site has been discovered. A two-stage approach to discovery, with the second stage requiring laboratory analysis before results are available to interpret, might work in some situations, but the amount of time needed to accomplish all the steps is likely to limit its applications.

For discovery investigations, Hassan's (1981) method of analysis seems more promising. He has developed a quantitative analysis that can be done in the field, with the laboratory preparation of each sample requiring between 8 and 18 minutes (Hassan 1981:385). The value of this method is that it can be accomplished in a single stage with quantitative analysis of each sample. Time requirements are less than those expected for Eidt's two-stage approach, but still substantial. In addition to the sample preparation, time is necessary for establishing the grid for sample collection, collecting the samples, and analyzing the results. The time requirements per sample might restrict Hassan's technique, mainly to intrasite investigations; and the fact that the two examples he uses to illustrate the technique are intrasite studies probably is more than coincidental.

Ahler (1973:129–130), Eidt (1977), and Proudfoot (1976) discuss the usefulness of various levels of different kinds of phosphorus and phosphate compounds for the identification of subsurface archaeological sites. Proudfoot (1976) in particular describes the difficulties of interpreting scores considering different phosphate compounds, variation in natural phosphate levels, and the number of samples taken in a given area. On balance, the identification and interpretation of variation in soil phosphorus or phosphate levels throughout large survey areas requires substantial detailed background data. The logistical problems of establishing a close-interval grid system, and extracting, analyzing, and interpreting thousands of samples for a large study area probably limits the efficiency of this technique for site discovery in most cases.

Sjoberg (1976:447–448) has made the most direct assertion in the recent literature that phosphate analysis is an uncomplicated and inexpensive discovery technique. He bases this assertion on what he interprets as the complete success of phosphate analysis as a major means of site discovery in northwestern Europe, specifically Sweden. Provan (1971:44–46), however, relates one example in which phosphate tests failed to discover expected sites in a 2.8-km² study area in Norway.

As Sjoberg describes his method, there are two main drawbacks to its widespread use for site discovery. First, he proposes a 25-m-interval systematic grid in a study area for the collection of samples. He acknowledges that this is a large interval and that phosphate-rich features and

anthropic soil horizons can easily be missed by it, thereby leaving undetected sites without abundant and widespread amounts of these constituents. The problem with so large an interval for discovery is emphasized by Sjoberg's strong recommendation that for intrasite examination a grid interval of 1 m is the maximum.

The time requirements of Sjoberg's procedure (1977:449–450) are the second major difficulty. His data indicate that the collection of each sample requires about 9 minutes. If the tab procedure, which Sjoberg recommends instead of Eidt's rapid field technique, is as time-consuming as Hassan's procedure, each sample will require between 17 and 27 minutes. Those are substantial time requirements for sample collection and lab analysis, and do not include additional time costs for transportation or analysis of the scores. The time required per sample, rather than theoretical questions about its widespread effectiveness, might limit the application of this technique to intrasite examination or discovery investigations covering relatively small areas. In fact, the detailed examples that Sjoberg (1976:452–453) presents are intrasite examinations for which he emphasizes in his conclusion (1976:454) the usefulness of phosphate analysis.

In summary, chemical tests have not been used for discovery investigations and probably are of limited use for discovery. The exceptions are tests for various phosphorous compounds that are stable and relatively widespread in archaeological features and anthropic soil horizons. Phosphate tests might be useful for site discovery when the area to be searched is relatively small. Successful applications also will require a short interval between tests, ample testing of natural chemical background values, and quantitative lab or field chemical analysis of the samples collected.

Remote Sensing Techniques

The techniques included under the term *remote sensing* include high- and low-level aerial photography and satellite imagery (Avery and Lyons 1981; Lyons and Avery 1977; Lyons *et al.* 1980). A variety of films and other sensor imagery types, imagery angles, and scales of measurement are associated with the techniques (Morain and Budge 1978). Remotely sensed imagery has two direct archaeological applications: (1) providing data for planning fieldwork logistics and stratifying investigation areas for sampling and (2) identifying specific site locations. Satellite photography and sensor imagery usually are limited to the former (e.g., Brown and Ebert 1980; Ebert *et al.* 1980; McCauley *et al.* 1982; Wells *et al.* 1981). Because the focus here is on site discovery, satellite remote sensing is not discussed further. Discussions of its equipment and uses for archaeologists as well as more detailed bibliographies are available in Lyons and Avery (1977), Lyons *et al.* (1980), Morain and Budge (1978), and Baker and Gumerman (1981:29–37). The substantial usefulness of aerial photographs for planning fieldwork logistics and sample stratification are not discussed either except in passing. The bibliographies of the works cited above include references to such applications, of which, Aikens *et al.* (1980) and Ebert and Gutierrez (1979, 1981) are specific examples.

Aerial photography has long been used for archaeological investigations, frequently as a site-discovery tool (Crawford 1924; Reeves 1936; see also many references in Lyons *et al.* 1980). The discovery of archaeological sites using aerial photography involves the detection of one of three possible archaeological anomalies (Lyons and Avery 1977:56–62): (1) above-surface features, especially structures, or anthropic soil horizons, (2) shadow marks caused by above-surface structural remains, and (3) plant or soil marks caused by subsurface features or anthropic soil horizons.

Discovery of the first two kinds of anomalies requires that archaeological remains be above or on the surface and visible from the air. This means that vegetation must be sparse or low enough to allow the direct view of surface remains, their low relief, or the subtle shadows they cast. In some regions favorable conditions have combined to make remote sensing an important, widely useful discovery technique. The successes of direct or shadow observation have been mainly in arid, sparsely vegetated sections of the American Southwest (Berlin *et al.* 1977; Schaber and Gumerman 1969; see many of the articles in Lyons 1976; Lyons and Ebert 1978; Lyons and Hitchcock 1977; Lyons and Mathien 1980). Less expected has been its occasional successful use in more densely vegetated regions, for example Harp's (1974, 1977) discovery of sod-wall remains of semisubterranean prehistoric structures in the Canadian subarctic by studying magnified 15,000:1-scale photographs stereoscopically. Surface-exposed shell middens in California have been detected directly using infrared aerial photography. Surface shell in the middens appeared as a bright white on the infrared imagery, making them stand out from their surroundings (Tartaglia 1977:45). In the heavily vegetated American Midwest also one type of archaeological site—earthen mounds—has been discovered through direct observation of aerial photographs (Baker and Gumerman 1981:9–10; Black 1967; Fowler 1977). In another case, stone fish-weirs were discovered in the Potomac River using aerial photographs (Strandberg and Tomlinson 1969).

Where dense vegetation and buried sites are the rule, the detection of plant and soil marks are the typical ways in which sites are discovered through the analysis of aerial photographs. The former are caused by differential plant growth of either natural or cultivated species due to variation in topography, soil moisture, or organic content caused by buried archaeological features, structures, or an anthropic soil horizon. Crop marks, a widely known type of differential plant growth, have been recognized and described, if not always correctly interpreted, for centuries (Fagan 1959). Soil marks occur at sites where substantial near-surface midden deposits have high organic-refuse content. Sharp contrast in soil color and reflection between the near-surface anthropic soil horizon and the surrounding natural soil matrix make the marks discernible (Baker and Gumerman 1981:12). In order for plant marks to be discovered, vegetation must be low-lying (Evans and Jones 1977; Munson 1967). Forest canopy is unaffected by most archaeological sites into or through which individual trees might grow, and even intermittent canopy cover can mask sites, preventing their discovery (Baker and Gumerman 1981:12; Gumerman and Neely 1972:526). Of course soil marks will be invisible whenever any vegetation is present.

In rare cases abrupt changes in the type of vegetation actually might point out site locations. Three examples are known from extensive marsh or swamp areas in Veracruz (Mexico), Florida, and Louisiana (Bruder *et al.* 1975; J. Ehrenhard 1980; Newman and Byrd 1980). In each case archaeological site locations correlate strongly and positively with slight elevations within the wetlands resulting in markedly different vegetation on the elevated areas. The vegetation differences are detected easily using aerial photographs. Topographic change independent of the archaeological sites themselves cause the vegetation difference in the Florida and Louisiana cases but the strong and steady correlation of sites with slightly elevated areas makes site discovery by association possible. In the Veracruz example, at least some of the extra elevation of site areas is caused by mounds constructed as part of prehistoric occupation areas.

Europeans, particularly in Great Britain and West Germany, have used oblique as well as vertical aerial photographs to detect plant marks caused by structural archaeological features at Iron Age and Roman period sites (Evans and Jones 1977; Martin 1971; see also many references in Lyons *et al.* 1980). Oblique photos have been used occasionally but far less frequently in the United States (Baker and Gumerman 1981; Black 1967; Fowler 1977; Lafferty 1977) where vertical photographs at a variety of scales have been the standard imagery. Imagery scale has varied, but

usually 1:20,000 has been the smallest scale usable for the detection of plant or soil marks (Baker and Gumerman 1981:36; Strandberg 1967). In many areas this scale might be too small but can be enlarged to suit the discovery need (Baker and Gumerman 1981:29–31). Imagery at the 1:20,000 and larger scales also are useful for logistical and sample design purposes.

Like scale, variation in the type of film used for aerial photographs affects detection of plant and soil marks. Put simply, there are four general kinds of film: black and white, color, black-and-white infrared, and color infrared (Avery and Lyons 1981:7–11; Lyons and Avery 1977). Each type has its own strengths and weaknesses that usually are specific to particular discovery applications. No single film serves all purposes; different types provide complementary information and for diverse kinds of information several types of imagery covering the same area should be studied simultaneously (Avery and Lyons 1981:9). Matheny (1962) presents a detailed comparison of black and white, color, and color infrared films for one heavily vegetated area. In general, black and white is a useful film for a variety of purposes (Avery and Lyons 1981:7; Fowler 1977), color for the identification of plant marks, land-cover types, and landforms (Baker and Gumerman 1981:32), and color infrared for distinguishing vegetation types (Baker and Gumerman 1981:32; Gumerman and Neeley 1972; Lyons and Avery 1977). For any particular situation, however, the usefulness or superiority of any film type might vary. For situations in which vegetation variation is important for discovery, color or color infrared can simplify and speed up interpretation (Strandberg 1967). In other instances, such as the direct detection of visible, obtrusive sites, these much more expensive films frequently are no more informative than normal black and white.

Some of the conditions necessary for aerial photograph interpretation to be effective for site discovery, such as vegetation, have been mentioned already. It also should be clear that to be discovered sites must be near the surface and contain distinct structural features such as house walls, foundations, or trenches, or prominent cultural soil horizons, such as dense shell or organic middens. Another important consideration for the successful detection of plant or soil marks is scheduling when the imagery is taken (Baker and Gumerman 1981:34–35; Martin 1971). The prominence of soil marks, for example, is affected by plowing and soil moisture; they are most prominent 2–3 days after a heavy rain (Lyons and Avery 1977:61). In some regions during certain seasons cloud cover regularly interferes with obtaining clear imagery (Baker and Gumerman 1981:35; Lyons and Avery 1977:85). Other considerations also should be taken into account. Plant marks, for example, are more or less prominent, therefore easier or more difficult to detect, depending upon the texture and composition of the soil (Lyons and Avery 1977:61).

In summary, for near-surface sites with abundant and widespread or at least prominent structural features or anthropic soil horizons, remote sensing is a very useful discovery technique given appropriate visibility conditions, imagery, and scheduling. Because of the scale of photographs, large areas can be examined relatively thoroughly and quickly, although the consistency of analysis and detection will vary with the visibility conditions at the time the imagery was taken.

The three types of techniques presented so far are likely to be effective mainly for the discovery of sites with abundant and widespread features, especially structural ones, and anthropic soil horizons. The more prominent, distinct, and larger the individual features or horizons, the more likely they are to produce an anomaly that is detectable by an instrument, a chemical test, or on an aerial photograph. If, however, an investigation aims in whole or in part to discover sites with less obtrusive, and in some cases positively unobtrusive, constituents, techniques discussed in the following sections will be needed. This is especially so where visibility is poor in part or all of the study area.

Subsurface Probes

Among the discovery techniques considered in this chapter, subsurface probes are discussed in the most detailed because of their widespread applicability, use, and potential effectiveness for site discovery. As archaeologists increasingly have undertaken surveys in areas with poor surface visibility, they have turned to subsurface probes as a discovery technique (Brose 1981; Casjens *et al.* 1978, 1980; Chatters 1981; Claassen and Spears 1975; Custer 1979; Feder 1977; Gatus 1980; Ives and Evans 1980; Lovis 1976; Lynch 1980; McManamon 1981a, 1981b, 1981c, 1982; Nance 1980a, 1980b; Otinger *et al.* 1982; F. Plog *et al.* 1977; Scott *et al.* 1978; Spurling 1980; Stone 1981a; Thorbahn 1977, 1980, n.d.; Weide 1976).

A wide range of probes has been used to discover sites. Although they more or less form a continuum in terms of size, shape, and volume, probes are described here as four distinct categories for ease of presentation. The dimensions given for each type of probe are generalizations rounded off for convenience; nevertheless they convey the magnitude of difference in size among the probes. Usually probe sizes are not measured precisely during discovery investigations. The aim typically is to complete a large number of similarly sized probes rather than a few carefully measured ones. The different kinds of probes discussed here are:

1. Soil cores: 2–3 cm (about 1 inch) diameter cylinders 50–100 cm (20–36 inches) long.
2. Auger holes: 1–15 cm (4–6 inches) diameter cylinders of soil dug to various depths, depending upon the soil and expected depth of sites.
3. "Divots": 30 × 30 × 8 cm (about 12 × 12 × 3 inches) volumes cut out of the mat of surface vegetation, overturned, and inspected.
4. Shovel tests: roughly shaped cylinders or rectangular volumes with a relatively wide range of dimensions: diameters 25–75 cm (10–30 inches) or surface dimensions of 25 × 25 cm (about 10 × 10 inches) to 100 × 100 cm (about 40 × 40 inches) with depths up to 150 cm (about 60 inches) depending upon soil type and expected depth of sites.

Subsurface tests are hardly a new discovery technique. Shovel tests have been used by archaeologists to discover sites since at least the early twentieth century (e.g., Moorehead 1918, 1931). The difference is that these early tests were sporadic and linked to informant information or hunches. Although this kind of traditional application continues, many contemporary applications are more rigorous in the placement of probes and coverage of study areas and are part of an explicit sampling strategy.

Before continuing with the consideration of subsurface probes' one special problem, the particular discovery problems related to deeply buried sites are touched on. With few exceptions, usually intrasite examinations (e.g., Chatters 1981; Gordon 1978; Muto and Gunn n.d.; Price *et al.* 1964; Reed *et al.* 1968), the depth of subsurface probes has been limited to about 1 m. More deeply buried sites are missed by most probes. When an investigation has as a goal the discovery of deeply buried sites, other subsurface techniques must be used. One technique already has been alluded to in a previous section—trenching, using a backhoe (Chapman 1976, 1977, 1978, 1981). Others also have used this technique successfully (Collins 1979; Reidhead n.d.).

The size and depth of trenches have been limited by the capability of the backhoe. Chapman (1977:3) describes trenches 13 feet long at the top tapering to 3 to 4 feet at the bottom. Depths range between 12 to 14 feet (Chapman 1978:3) and 1 to 13 feet (Reidhead n.d.:6). In all these

cases, toothless backhoe buckets were used. Sites typically were identified by inspecting trench sidewalls for artifacts, features, and cultural soil horizons.

The massive volume excavated by each deep trench requires large amounts of time and limits strictly the number of trenches that can be excavated. Intensive coverage of large areas is impossible without substantial amounts of money. For this reason all the investigators cited here were forced to leave large intervals between trenches. Each acknowledges the difficulties this causes for site discovery and site delimitation as well as for the accuracy of the sample of sites discovered and the precision of estimates based upon it (Chapman 1977:9–11, 1978:91; Reidhead n.d.:8).

The problems for the discovery of deeply buried sites have been merely introduced here, not discussed in detail and by no means resolved. The areas where this technique is relevant usually can be identified using existing geomorphic data. All archaeologists should be cognizant of the potential problem whenever they work in areas where substantial aggradation might have occurred. For further discussion and detail readers are referred to the works cited and to investigators pursuing the problems.

Soil Cores

Soil cores initially seem an attractive technique. They are collected using soil tube samplers such as those made by the Oakfield Company (Forestry Suppliers 1980:144–145). Their small diameter makes them relatively easy to use in some soil types and they can be quickly recorded (Casjens *et al.* 1980:10). In southeastern Massachusetts, Thorbahn (1977, 1980, n.d.) supervised a survey of the I-495 highway corridor (21 km × 120 m) that used as a discovery technique soil cores with follow up shovel tests where anomalies occurred. Based upon this work, Thorbahn (1980:16) considers soil cores "the most efficient means for preliminary subsurface testing over a large survey area..." The anomalies detected usually were "flecks of charcoal or thin bands of oxidized soils (Thorbahn n.d.:6)." Thorbahn mentions that during excavations at the 13 I-495 sites for which he presents data "scatters of charcoal flecks and patches of discolored soil were observed throughout" (n.d.:6) each site. Such a frequency and widespread distribution of anthropic soil horizons is not expected based upon the models of archaeological site constituents developed above.

Others who have used soil cores have not detected, or perhaps have detected but not recognized, the anomalies described by Thorbahn. For a survey of a 25 ha area in Washington, Chatters (1981) used 2.5 cm diameter soil cores in a systematic grid with a 50 m interval. He discovered two anthropic soil horizons, both "middens," one historic and the other prehistoric. Casjens *et al.* (1980:10) describes soil cores as effective for discovering dense shell deposits but not other sites or parts of sites. Luedtke (1980:38) concurs with these conclusions, noting that soil cores "may miss sites with sparse shell and will be least useful where shell is not found at all." None of these investigators confirms the occurrence of the type of anomaly detected in the I-495 study.

If soil cores detect only features or anthropic soil horizons, which are not widely distributed or frequent within many sites and are absent from others, the interval between individual cores must be relatively small. Because cores can be collected and recorded quickly, small intervals are possible; but the shorter interval seems not to make up for the limitations of the site constituents they detect. In a review of discovery investigations using soil cores in Rhode Island between 1977 and 1979, Robinson (1981:49) noted an overall lack of efficiency in the use of cores for discovery. Fewer than half (9 out of 19) of the anomalies detected by soil cores in these studies proved to be archaeological sites after intensive subsurface testing. Because discovery of sites

using cores requires verification with larger subsurface units and might be accurate less than 50% of the time, the efficiency of the preliminary core testing is more apparent than real.

It seems clear that soil cores will be effective for discovering only those sites with abundant and widespread features or anthropic soil horizons (Robinson 1981:49). In a controlled comparison of discovery techniques at eight sites undertaken as part of the Cape Cod National Seashore Archeological Survey, only 1 of 100 soil cores taken within site areas detected a site constituent and that was a piece of plaster extracted along with the soil (McManamon 1981a; 1981c:202–220). The soil core profiles within known site areas did not show clearly anomalous color or texture patterns indicative of features or cultural soil horizons.

The comparison mentioned in the last paragraph tested three discovery techniques: cores, augers, and shovel tests. Transects of various lengths, typically 100–200 m long, were placed so that they fell partially within and partially outside site boundaries. Cores, auger holes, and shovel tests were placed adjacent to each other 1–2 m apart along each transect. Spacing along the transect varied; cores and augers were placed every 5 m, shovel tests every 12.5 or 25 m. Placement of the probes was designed to give each technique as equal as possible a chance to discover archaeological remains in any particular location. Shovel tests were not "confined only to site areas with high artifact densities," as mistakenly reported by Nance (1983:327–328) based upon incorrect information in Thorbahn (n.d.:13).

Soil cores present some technical problems as well. In dry, sandy soils, the cylinder of soil often fell out of the tube sampler as it was extracted. In clayey or gravelly soils, insertion of the sampler is difficult or impossible (Chatters 1981; Thorbahn n.d.:9; Trubowitz 1973:7–8). Thorbahn (n.d.:9) notes also that the subtle anomalies detected in the I-495 sites were obscured by deep plowzones or waterlogged soils.

Soil cores have been useful for the intrasite examination of some kinds of sites. They can "aid in defining the spatial distribution of known sites" (Trubowitz 1973:7–8). At two sites in Washington state, Chatters (1981) successfully used close-interval (5 and 2 m) coring to (1) determine the depth, horizontal extent, and stratification, (2) monitor overburden stripping, (3) delimit small activity areas, and (4) assist the stratigraphic excavation of particular excavation units.

Overall, it appears that soil cores are a technique less attuned to site discovery than to the examination of known sites, or portions of them, with relatively dense features or anthropic soil horizons. As a discovery technique it will effectively and efficiently discover sites with large numbers and high densities of these kinds of site constituents. Many sites, however, do not contain such constituents, or contain few of them. The inability of cores to detect artifacts, the most common and widespread archaeological anomaly, makes soil coring a discovery technique for specialized applications rather than general purposes.

Auger Holes

Like soil cores, auger holes are cylinders of soil, but they are larger, with diameters ranging from 10 to 15 cm (about 4 to 6 inches). The auger hole contents are inspected to check for artifacts or feature fill and the profile of the hole is inspected for features or anthropic soil horizons. Auger holes, therefore, can detect three principal site constituents: artifacts, features, and anthropic soil horizons. Because of the hole's narrow diameter, however, profile inspection and therefore feature or soil horizon detection can be difficult. Several investigators have noted that auger holes are too narrow or that the profile cannot be cleaned sufficiently, especially in its deeper parts (Casjens *et*

al. 1980:11; Claassen and Spears 1975:126). Auger holes have been dug with a variety of tools, including standard posthole diggers, bucket augers, and hand or motorized twist augers (Forestry Suppliers 1980:26–30, 143–145). Wood (1975:2) describes the technique: "we found that a pair of manually operated post-hole diggers were an inexpensive, portable, and effective tool for locating buried or obscured sites. With some practice a person can dig a small shaft as deep as 1.5 meters and bring out 10 cm core sections which in turn can be inspected for evidence of human occupation." Bucket augers are used similarly, except that the soil is held by friction alone and lifted out in a wide tube. As described below, dry and loose soils present a problem for bucket augers. Ferguson and Widmer (1976:23–29) used a mechanical screw auger mounted on a four-wheel-drive truck; the soil brought to the surface by the auger was screened to recover artifacts. Percy (1976:31) used a Sears' smaller power screw auger. Auger holes have been used in the eastern (Casjens *et al.* 1980; Ferguson and Widmer 1976; Percy 1976; South and Widmer 1977; Wood 1975) and middle United States (Claassen and Spears 1975; Leehan and Hackenberger 1976; Scott *et al.* 1978) and in Mesoamerica (Fry 1972) for examination of known sites as well as for discovery investigations.

Ferguson and Widmer (1976) report that the 6-inch-diameter screw auger they used discovered artifacts 80% of the time within site boundaries during a survey in the Middle Savannah River Valley in Georgia. The sites at which the auger holes detected artifacts, however, contained dense artifact scatters covering wide areas. They cautioned that "smaller sites with different types of debris might not prove so obvious when sampled by [auger holes]" (Ferguson and Widmer 1976:28). Wood (1975:10), despite an enthusiastic endorsement of the technique, cautions about its unreliability when artifact density is low. At Tikal, Guatemala, Fry (1972:261) reports the effective use of auger holes for discovering artifact clusters and related structures. At another Maya site, Chalchuapa in El Salvador, however, the same technique was unsuccessful, at least partially because of a lower artifact density (Fry 1972). For New England, Casjens *et al.* (1980:11) note that "prehistoric sites with smaller amounts of cultural material might not be found" using auger holes.

In a controlled comparison of discovery techniques done as part of the Cape Cod National Seashore Archeological Survey, bucket augers used within eight known sites recovered artifacts only 45% of the time (54 recoveries/ 119 holes) (McManamon 1981a; 1981c:202–205). This rate, which is well below that for shovel tests, probably is due partially to the problem of extracting loose dry sand from the auger hole. Nevertheless, it is far below the 80% success rate of Ferguson and Widmer cited above and, along with the other examples, raises questions about the effectiveness of auger holes as a general discovery technique.

The effectiveness of auger holes for site discovery seems to be affected strongly by the intrasite distribution of artifacts. They can detect artifacts when the artifacts are abundant and widely distributed. Auger holes are less likely to discover artifacts when the artifacts are either scarce though widely distributed or plentiful but spatially clustered. The relatively small volume of soil extracted and inspected by auger holes seems to be the reason for their peculiar pattern of effectiveness. The effect that variation in probe volume has upon the likelihood of recovering artifacts is considered below. Readers should note that none of the examples of auger use cited above reported frequent or consistent discovery of features or anthropic soil horizons. The technique certainly is capable of detecting them and it is unlikely that all the investigators cited would have ignored or failed to notice features and anthropic soil horizons if they had occurred. The failure to detect these site constituents, therefore, supports the hypothesis that features and anthropic soil horizons are infrequent or, if abundant, are highly clustered and difficult to detect in most cases.

Several investigators report technical problems using the tools available to extract the soil from auger holes. In Arkansas, Claassen and Spears (1975:126) tested the usefulness of a 7-cm-diameter auger. They termed it "awkward and inefficient"; root and rocks in the soil prevented completion of three out of six tests. The single completed test took 40 minutes. The other two were abandoned without completing them after 40 minutes had been spent digging each. Casjens *et al.* (1980:11) agree partially: "post hole diggers work well in sand; they cut roots efficiently but do not work well in rocky soil." They add that digging an auger hole is back-breaking work. Loose dry sand is another problem for posthole diggers (South and Widmer 1977:129). The sand cannot be held between the digger blades to remove it from the hole. Bucket augers rely on friction and a rigid soil structure to hold sections of soil in the bucket while they are lifted out of the auger hole. For this tool even wet sand can be difficult to extract. This was a major problem with bucket augers tested in sandy soil on Outer Cape Cod, Massachusetts (McManamon 1981:202–205). Soils with some clay, wet silt, or organic material were much less trouble to extract; however, dry sandy soil was the most common type along a number of the transects tested. In many cases the soil had to be dug from the auger hole with a garden hand shovel or trowel after the bucket auger failed to remove it. Similar problems forced the abandonment of bucket augers as a site examination technique in an investigation of a historic period site in Lincoln, Massachusetts (Pratt 1981:6).

In summary, auger holes can be an effective, efficient technique of site discovery. The increase in diameter from soil cores allows the auger holes to detect a wide range of site constituents. They should be able to detect three principal site constituents: artifacts, features, and anthropic soil horizons. However, sites without abundant, widespread artifact deposits seem to be missed by auger holes. Because they can be dug and recorded quickly, given appropriate soil conditions (that is, a nonsandy soil without dense rocks, gravel or roots), auger holes can be used for discovery investigations covering large areas if sites with abundant and widespread artifact deposits, features, or anthropic soil horizons are the target population.

Divoting

William Lovis brought national prominence to the problem of site discovery in densely vegetated environments with his 1977 *American Antiquity* article. Lovis used a discovery technique termed *divoting*. Divots are 25–30 cm (10–12 inch) squares cut into the forest floor or vegetation mat. The mat and adhering topsoil then are flipped over and inspected visually for artifacts. The exposed soil below the mat is inspected for features. Depending upon the soil profile, either topsoil or the topsoil and subsoil are inspected. In northern Michigan, where topsoil is thin, Lovis (1976:367) was able to inspect the interface between the topsoil and subsoil. The topsoil adhered to the vegetation mat and the top of the subsoil was exposed in the cut. In regions with thicker topsoil, a divot would not penetrate to the subsoil; only one possible horizon of the soil would be exposed and inspected in the cut, although all the topsoil above the cut level can be scraped off the bottom of the mat and inspected visually in the process (Williams 1976:5–6).

The relatively small volume inspected by divots suggests that they might be subject to constraints regarding the kind of sites they discover similar to those that seem to affect auger holes. The volume of a divot is slightly larger than the volume of an auger hole: a 30 × 30 × 10 cm divot has approximately a 9000 cm³ volume and a 15 cm diameter, and a 50 cm deep auger hole has approximately 8800 cm³. In a careful critique of Lovis's article, Nance (1979) pointed out just this problem of using such a small-sized unit for discovery.

All in all, divoting does not have much to recommend it as a discovery technique. Like surface clearing, divots inspect a surface rather than a soil volume. Divots share with auger holes the

unfortunate likelihood of missing sites without dense and widespread constituents. Unlike auger holes, however, the depth below surface that divots can test is very shallow. Sites buried by practically any soil aggradation will be missed as a matter of course. Furthermore, inspection is exclusively visual. Other subsurface probes can, and often do, involve screening the contents to recover artifacts. This is important because the artifacts by which a site is detected are typically small and often are dirt-coated or embedded in clumps of soil. Quick visual inspections of divots probably are insufficient to detect dirty embedded artifacts, especially the tiny nondistinctive ones that compose the bulk of most site assemblages. All in all, divots have a very limited application for site discovery because of their small volume, shallow excavation, and inability to incorporate screening for inspection.

Shovel Tests

Shovel tests are the largest-volume subsurface probes. At the surface their dimensions range from 25 to 75 cm diameters for circular tests and 25 to 100 cm on a side for square ones. Depths usually vary according to the depth of archaeological deposits or their expected depth, but depths over 100 cm are physically difficult to excavate and therefore rare. Tests with a circular surface shape usually are cylinders, although below 50 cm their shape tends to become more conical because of physical constraints. Similarly, square units are less cubic and more pyramidal as their depth increases. These slight changes can be accounted for as necessary for comparisons among shovel tests during data analysis. Because tests must be dug quickly, field supervisors must continually monitor testing to maintain as much consistency in shovel test size and shape as possible.

Shovel tests like postholes discover artifacts, features, and anthropic soil horizons. Unlike postholes, shovel test dimensions are large enough for easy inspection of the complete profile on all walls of the unit for its complete depth. Artifacts are recovered from the shovel test fill. Frequently all contents of each test are screened to facilitate the recovery of small artifacts (Bergman 1980:37; Casjens *et al.* 1980; McManamon 1981a, 1981c; Nance 1980b:172; Spurling 1980:32ff; Weide 1976), although some investigators have relied upon visual inspection of the test fill (A. Goodyear 1978:9; House and Ballenger 1977:46). Smaller shovel tests have surface dimensions similar to those of divots, however, they are dug much deeper and therefore inspect a larger volume; in addition, shovel tests that are screened have their contents inspected much more carefully than divots. These additional characteristics of shovel tests make them more likely to detect one or more site constituents.

Large volume seems to be the most important factor increasing the effectiveness of shovel tests over other techniques. In a controlled comparison of auger holes versus shovel tests (40 cm diameter) within site areas on outer Cape Cod, Massachusetts, test pits were over 70% more effective than auger holes (78% of the shovel tests recovered artifacts, only 45% of postholes) although the soil from both types of tests was screened (McManamon 1981a, 1981c, 1982). This is not to suggest that screening is unimportant. The available data suggest that discovery effectiveness is far greater when the soil from tests is screened rather than inspected visually. The two examples suggest, however, that screening alone does not increase the effectiveness of postholes or divots to the level of test pits. The greater volume of the latter is a crucial factor in its effectiveness as a discovery technique.

The price of the increased likelihood of site discovery when larger-volume tests are used is time, which, as Henry Ford and a host of others since have stressed, is money. Larger-volume tests require longer to dig, screen, collect from, and record so they result in higher labor cost per test. For this reason shovel tests usually are spaced more widely apart within quadrat or transect

sample units than are soil cores or auger holes. Larger spaces between test units complicate the logistics necessary for precise unit location. Investigators aiming to discover sites cannot afford to locate test pits as precisely as if site examination or excavation were the activity at hand. Each pit must be located precisely enough to ensure adequate coverage of the transect or quadrat, but quickly enough to allow the field workers to cover as much ground as possible during a workday. Controlled pacing and compasses, rather than long tapes and transits, are the appropriate means of arranging test-pit grids in quadrats or along transects. As with consistency in test-pit size and shape, care by field crew and supervisors is an essential ingredient for success.

Shovel tests, when their contents are screened to retrieve artifacts, seem likely overall to be the most effective of the subsurface techniques that have been used for site discovery. They have an important combination of advantages. First, they will detect the most common and widespread site constituent—artifacts—plus two others—features, and cultural soil horizons. Second, their relatively large volume gives them a greater likelihood of including one or more artifacts or remains from features or anthropic soil horizons within a site area. Screening is a crucial part of the shovel test technique. It overcomes visibility problems caused by soil adhering to artifacts and permits the recovery of small artifacts that could be missed easily, even by careful troweling. In general, larger shovel tests are likely to be more effective at discovery than are smaller ones. The general case, however, might be reversed because of specific circumstances or project goals. In some situations, for example, it might be desirable to excavate a larger number of smaller tests than a small number of larger ones.

Each site discovery investigation requires individual attention and perhaps a unique solution to the problems confronted. When subsurface probes appear to be the answer, it is crucial that the variety of available probes be considered in light of the problem at hand. Two concerns must be balanced in deciding among subsurface probes: (1) the artifact, feature, and anthropic soil horizon frequencies and distributions expected within the sites being sought, plus the size of the sites, all of which affect the effectiveness of different kinds of probes, and (2) the cost of different types of probes. For convenience of presentation the costs are discussed first.

The Cost of Subsurface Probes

Information about the cost of using different subsurface probes is neither widely available nor easily compared when it is found. Total project costs are not good measures for comparison because they vary according to a variety of factors independent of discovery technique costs, such as remoteness of the study area, amount of travel to and from portions of the area being tested, the ease or difficulty of movement due to vegetation or topography, and the ease or difficulty of excavation due to soil conditions. The combination of these kinds of factors makes total project costs unique to the specific conditions encountered and the manner with which they were dealt. Cost in dollars is not the easiest way to compare techniques either. Dollar costs depend upon the cost of labor, which can vary independently of the discovery technique used. Instead, in the examples below, cost is figured indirectly in the time required to complete individual tests or for test coverage of standard-sized areas. Time estimates then can be used with the standard cost of labor for the project to compute dollar costs if they are desired.

Two ways of comparing the time requirements of different subsurface probes are possible. One is to calculate only the time required for excavating, inspecting, recording, and backfilling individual probes of different sizes. This is a basic cost that can be multiplied by the number of probes planned, and added to related costs such as the costs of setting up a test grid, moving between tests, and traveling between areas to be tested to calculate total cost of tests. A few examples of individual test time requirements are available. More commonly, the time needed to

test a particular-size area is reported. Area coverage time estimates combine the time required for all the activities just listed above and are associated with a particular number and alignment or system of aligning the probes. Being linked to specific applications, these statements of time requirements are less easily compared than those for individual probes.

The time requirements of individual probes is available from a few reports, but for shovel tests only. Nevertheless, the available information is useful, if not comprehensive. Data from the 1979 season of the Cape Cod National Seashore Archeological Survey (McManamon 1981b, 1982) indicate the time required simply to excavate, sift through, record, and backfill moderate-size shovel tests (Table 4.8). These data have two principal implications. First, there is substantial variation between the time required within and outside site areas. Some of the additional time within site areas is due to more careful recording of soil data and the increased time needed to collect artifacts. Undoubtedly some is due to a heightened expectation of finding artifacts within a site area that makes crew members unconsciously increase their attention to the inspection of screens for small artifacts and test profiles for features or anthropic soil horizons. Investigations that plan to use shovel tests for examination within site areas will require more time for each test than those that limit their activities to discovery alone.

The second noteworthy point about the time requirements is the relative rapidity with which shovel tests can be done. The rough average of 8 minutes per probe outside site areas, for example, is at the low end of the 8–18 minutes per sample needed for the chemical analysis alone in Hassan's quantitative field chemical test (Hassan 1981:385). Even within site areas only seven shovel tests required more than 20 minutes to complete. The overall average of roughly 20 minutes per test is misleadingly high because of these few extreme cases.

Comparable data on the time requirement for individual shovel tests are very sparse. House and Ballenger (1976:52) estimated that each 1 m × 1 m × 10–15 cm test they excavated required 15–20 minutes to dig, examine carefully (but not screen), and backfill. By comparing these figures with those for the data from the Cape study the extra time required for screening can be estimated (Table 4.9). These estimates assume that apart from the screening all other activities done for each shovel test were similar. Because this is not certain, the estimated time requirements are only approximate. More accurately, they are approximations rather than specific estimates of time requirements. The figures suggest, however, substantial overlap in the rates at which soil is inspected for shovel tests that were screened and those that were not. The decrease in the rate of soil inspection due to screening might well be acceptable given the more reliable artifact identification afforded by screening.

Those archaeological reports that include information about time requirements for subsurface probes typically provide them in terms of the time required to test a standard-size area using particular probe sizes and spatial arrangements. Thus, Thorbahn (n.d.) reports that in the forests and fields of southeastern New England an average of 40 soil cores/hectare using random walk transects, plus the shovel tests necessary to confirm core anomalies as actual archaeological sites, required 1.5 person days. Also using soil cores but on the floodplain of the former Black River near Seattle in western Washington, Chatters (1981:Table 1) records that 80 hours (10 person days) were needed to test a 25 ha area using a systematic grid with a 50 m interval. He also reports the time required for two other soil core grids, one with a 5 m interval and the other with a 2 m interval. Spurling (1980:45ff.) records that 500 × 500 m in square quadrats (25 ha) with 100 1 × 1 m in tests in a systematic unaligned arrangement required 12–16 person days in the Upper Peace River Valley of eastern British Columbia. Another survey in a different, but similar, part of

Table 4.8

Time Required for Shovel Tests^a

Sample unit-site ^b	Time per test (minutes)		Comments
	\bar{x}	Range	
2 19BN285	16	—	
2 19BN286	13	10–20	
5 19BN289	15	8–18	
6 19BN287	9	5–10	
7 19BN288	35	10–85	only 2 > 20 minutes
10 19BN273	15	7–19	
10 19BN274	24	15–70	only 1 > 25 minutes
10 19BN275	32	15–75	only 1 > 20 minutes
19 19BN276	—	5–32	only 3 > 20 minutes
Outside site areas ^c			
2	11	10–12	
3	12	7–24	
4	6	5–10	
5	9	7–12	
6	9	5–15	
7	10	9–10	
8	7	5–18	
9	10	10–10	
10	14	7–30	
11	9	5–20	
12	5	2–7	
13	7	5–11	
14	10	5–28	
15	9	4–14	
16	5	3–10	
17	9	5–15	
19	7	4–12	
20	9	5–13	
21	6	3–11	
22	5	2–12	
23	6	3–10	
25	5	2–8	
26	11	5–25	

^a Shovel tests 40 cm in diameter, dug into glacial soil horizon, usually 25–75 cm deep. Data from 1979 field season, Cape Cod National Seashore Archaeological Survey. Within sites averages are based upon 5 to 10 tests. Outside site areas averages and based upon 10 to 3 tests.

^b Overall average about 20 minutes.

^c Overall average about 8 minutes.

the Peace River drainage required only 12–14 person days/quadrat. Spurling (1980:48) accounts for the difference by variation in travel time among quadrats, the time required to locate quadrats, and crew size.

Table 4.9
Estimated Approximate Time Requirement of Screening

Estimated time required without screening ^a
100 x 100 x 10–15 cm shovel tests
Approximate volumes = 150,000–100,000 cm ³
Approximate time required = 10–15 minutes
Approximate rate = 6600–15,000 cm ³ /minute
Estimated time required with screening ^b
40-cm diameter x 25–75 cm shovel tests
Approximate volumes = 31,000–94,000 cm ³
Approximate time required = 8–20 minutes ^c
Approximate rate = 1600–11,800 cm ³ /minute

^a House and Ballenger (1976:52).

^b Cape Cod National Seashore Archaeological Survey, 1979 data.

^c For overall average, see Table 4.8.

Together these three examples provide some comparisons between shovel tests and soil cores as well as between a single linear array of probes and systematic grid arrays (Table 4.10). Comparison of the estimated number of soil cores versus 1 × 1 m shovel tests per person day gives a hint of the substantial differences in time requirements. Missing from this comparison, however, is any consideration of the depth of the different probes or variation in soils into which the different probes were made. A soil core sunk 2 m in or more into floodplain silts might require more time than a 1 × 1 m unit dug to a relatively shallow 25 cm. More detailed data comparing soil cores, augers, and shovel tests with consistent depths and soil conditions are presented below.

The other interesting comparison exists between the transect alignment (Thorbahn n.d.) and the systematic grids (Chatters 1981). The logistical requirements of laying out a formal grid might be a contributing factor for lower rates that Chatters reports. Movement between soil core locations might also account for the lower rates because, as the interval between cores decreases, the rate increases. Formally established systematic grids require substantial commitments of time and consequently reduce the rate at which probes can be completed.

TABLE 4.10

Comparisons of Time Requirements: Soil Cores versus Shovel Tests and Transects versus Grids

Investigation	Probe type and array	Probe interval (m)	Reported rate (No. probes / tested area / person-days)	Estimated rate for 1 ha (probes / person-days)	Estimated probes / person-day ^a
Chatters (1981: Table 1)	soil core, systematic grid	50	105 / 25 ha / 10	4.2 / 2.5	2
		5	47 / .15 ha / 4	313.3 / 26.6	12
		2	107 / .025 ha / 6	4280 / 240	18
Thorbahn (n.d.)	soil core, linear, random walk transect	10	40 / 1 ha / 1.5 ^b	40 / 1.5	27 ^b
Spurling (1980: 32–37)	1 × 1 m shovel test, stratified, systematic, unaligned grid	50 ^c	100 / 25 ha / 12-16	4 / 1.6-2.0	2–3

^a Values are rounded to nearest integer.

^b Includes time needed for shovel tests to confirm anomalies in soil cores.

^c Approximate

On the other hand, probes arranged in systematic grid patterns can provide for more even coverage of quadrat sample units than can narrow transects, and site frequency estimates based upon data from systematically tested quadrats are less biased by boundary effects than are transect-derived ones (S. Plog 1976; S. Plog *et al.* 1978:395–400). Successful use of grids for discovery investigations requires a careful mix of speed and precision. To paraphrase George Cowgill (1968:367), do not use a transit and tape when a pocket compass and pacing will do.

The final set of data presented in this section provides more details on the different time requirements of soil cores, augers, and shovel tests. Again, these data come from the 1979 field season of the Cape Cod Archeological Survey (Table 4.11). Shovel tests were arrayed systematically at 25 m intervals within 100 × 200 m survey units. Each unit contained 32 tests. If artifacts were discovered in a shovel test, additional shovel tests were placed around it. As an experiment, soil cores and augers were excavated at 5 m intervals along a number of transects coinciding with shovel test lines within 11 survey units. The shovel tests were generally 40 cm in diameter and 25–75 cm deep, depending upon the depth of postglacial deposits. The summary statistics in Table 4.11 indicate that soil cores and augers can be completed, on the average, about 2.5 times as quickly as 40 cm diameter shovel tests. A substantial overlap (24–40) exists in the ranges of soil core, auger, and shovel test rates, however. These data contradict the lopsided comparison of 1 × 1 m shovel tests versus most of the soil core examples in Table 4.10 and probably more accurately indicate the magnitude of difference in time required by these different probe techniques.

TABLE 4.11

Rates of Shovel Test, Auger, and Soil Core Completion^a

Shovel test ^b			Auger and soil core ^c		
Survey units	Test date	Tests/person-day ^d	Survey units	Test date	Tests/person-day ^d
12, 16, 22	9 July 79	19	40	24 July 79	30
14	9 July 79	8	48	27 July 79	50
25, 31, 33	10 July 79	14	35, 38	30 July 79	28
15, 21	10 July 79	11	4, 33, 52	31 July 79	72
31	12 July 79	15	1, 5, 44	1 August 79	72
47	12 July 79	11	3	2 August 79	24
31, 37, 48	16 July 79	13			
36, 43	16 July 79	12			
48, 49	17 July 79	14			
35, 44	17 July 79	13			
40, 49	18 July 79	16			
34, 35, 42	18 July 79	17			
29, 38, 40	19 July 79	20			
52	20 July 79	22			
23, 28	28 July 79	15			
20, 32	24 July 79	15			
27, 32, 51	25 July 79	12			
51	26 July 79	10			
35, 38	30 July 79	14			
39	30 July 79	15			
33, 39	31 July 79	13			
33	1 August 79	28			
33	2 August 79	28			
39, 97	6 August 79	30			
60	7 August 79	12			
59	7 August 79	14			
58, 59	8 August 79	15			
57, 58, 59	9 August 79	17			
57, 56	13 August 79	20			
56, 129	14 August 79	14			
76, 75, 89	14 August 79	19			
150, 128, 149	15 August 79	24			
67, 68	15 August 79	13			
75, 68	16 August 79	17			
93, 94	16 August 79	21			
70	17 August 79	21			
79	20 August 79	17			
95	20 August 79	21			
77, 80	21 August 79	22			
96, 97	21 August 79	18			
80, 87	22 August 79	23			
97, 151	22 August 79	21			
87, 86	23 August 79	16			
88, 143, 123	23 August 79	20			
125	24 August 79	16			
123	24 August 79	24			
91, 113	28 August 79	40			
141, 101, 100	28 August 79	24			
134, 136	29 August 79	37			
118, 121	30 August 79	20			

^a Cape Cod National Seashore Archaeological Survey, 1979 season.

^b $\bar{x} = 18$; $Md = 17$; range = 8–40. 25-m interval.

^c $\bar{x} = 46$; $Md = 40$; range = 24–72. 5-m interval.

^d Approximate rate.

Two other noteworthy points are suggested by these data. First, the rate of shovel tests/person days increased as the season progressed and crews became more familiar with the technique and method. Second, shovel tests inspect volumes of soil more efficiently than do cores or augers. Cores and augers on the average can be done about 2.5 times faster than shovel tests, but whereas a shovel test 40 cm in diameter and 50 cm deep inspects about 63,000 cm³ of soil, an auger 10 cm in diameter and 50 cm deep inspects only about 3900 cm³. The shovel test inspects over 16 times the soil volume of the auger for less than 3 times the cost. Enough augers to equal the volume of a given-size shovel test cannot be done as quickly as the shovel test. The question of which technique is more effective and cost-efficient then revolves around the size, artifact frequencies, and intrasite artifact distribution of the sites that are to be sought by an investigation.

Armed with this kind of cost information, it is possible to estimate the numbers of different probes that can be done within specific time periods and project budgets. But the information is useful for more than predicting budgets and time requirements. It can be used to choose the appropriate probe size for specific discovery problems. Consider, for example, a situation in which the size, artifact density, and artifact distribution of the sites of interest for a discovery investigation can be predicted reliably. As is discussed in the next section, the probability of probes of different sizes discovering such sites can be estimated roughly, as can the probability of discovery using differing numbers of different size probes. These sets of probabilities then can be evaluated in light of the rate at which different-size probes can be completed. A decision upon the discovery technique to be used made with such comparative information in hand would be truly informed regarding the cost-effectiveness of a larger number of smaller probes versus a smaller number of larger ones. In the next section ideas of how discovery probabilities are affected by site size and artifact abundance and density are explored.

FACTORS THAT AFFECT SITE DISCOVERY USING SUBSURFACE PROBES

The detection of a site using a type of subsurface probe depends upon four factors: (1) site size, (2) the frequency and intrasite distribution of artifacts, (3) the size of the probe, and (4) the number and spacing of probes.

This section specifically considers subsurface probes; however, the four factors, with some modification, also influence the likelihood of site discovery using other techniques that detect site constituents other than artifacts. The frequency, spatial distribution, and size of features and anthropic soil horizons, for example, have important effects upon the likelihood of site discovery using soil cores, chemical tests, or instrument techniques, as do the number of cores or spacing of chemical or instrument readings. Therefore, although these constituents and techniques are not discussed explicitly here, insights drawn from this section might be relevant for them.

Archaeologists have begun to examine some of these factors in order to assess directly their effect upon archaeological data sets. Regarding site discovery, Krakker *et al.* (n.d.), Lovis (1976), Lynch (1980, 1981), Nance (1979, 1980a, 1980b, 1983), Scott *et al.* (1978), Stone (1981a, 1981b), and Thorbahn (n.d.) are directly applicable. In addition, several papers on site

examination include discussions relevant for discovery with minor modifications only (Chartkoff 1978; Nance 1981:153–160; Nance and Ball 1981).

The first two factors—site size and artifact frequency and distribution—can be regarded as independent variables. The former were discussed generally in the earlier section on site constituents. Both are among the given characteristics of the archaeological record. The other factors—probe size and number and spacing of probes used—are controlled to some extent by the investigator who decides the size of probe to be used and the number of probes to be placed within the study area. Abstract models of relevant site characteristics as well as specific archaeological sites data have been used to examine the effect of variation in probe size or number upon discovery likelihood. The examples described below involve more or less simple versions of the archaeological record and site discovery investigations. They should not be generalized widely or uncritically; rather they provide ideas or guidance for the analysis of more complex specific situations. Remember also that successful *discovery* using subsurface probes requires the recovery of only one artifact to indicate the presence of a site (Nance 1981:153ff.; Stone 1981a:45–49, 1981b).

Probe Size

Parts of the preceding section suggested the importance of probe size for successful site discovery. Soil cores, which have the narrowest diameter among subsurface probes, appear to be relatively ineffective for the discovery of sites without abundant and widespread features or cultural soil horizons because their small diameter nearly always prevents them from discovering artifacts. Although that particular problem is skirted by subsurface probes with slightly larger dimensions, the smaller of these probes appear less likely to discover sites without abundant and widespread amounts of artifacts than are probes with larger dimensions. Once more, an example comparing augers and shovel tests comes from a test of discovery techniques conducted as part of the Cape Cod National Seashore Archeological Survey (McManamon 1981b:204–205). The overall results indicate that augers with diameters of about 10 cm are only 58% as effective as shovel tests with 40 cm diameters at discovering artifacts within site areas. This is so despite the fact that augers outnumber shovel tests by approximately 4 to 1 in this experiment. Considering only the results from the prehistoric sites tested, the augers do slightly better but still are only 67% as effective as the shovel tests. The prehistoric sites where the tests were done have estimated artifact densities of 45 to 50/m² of the surface area, which is roughly the average for all prehistoric sites discovered by the survey.

A more abstract model using a variety of values for artifact abundance and density permits comparisons among a wider range of probe sizes (Table 4.12). Imagine an archaeological site, or a portion of a site, 10 m square and 50 cm deep. Within this volume envision artifacts spaced evenly, vertically as well as horizontally, throughout the volume of the site. With this kind of even distribution the probability that different-size probes will discover artifacts is a function of the number of artifacts in the site matrix and the size of the probe. The greater the number of artifacts and the larger the probe size, the greater the probability that a probe will contain an artifact, thus discovering the site. As the number of artifacts decreases, the probability that small probes will be successful decreases much sooner than the probability of success using larger ones

TABLE 4.12

Probabilities of Single Subsurface Probe Discovering Site^a

Probe diameter (cm) ^b	Number of probes (per 10m ²) ^c	Number of artifacts in site				
		10,000 (100/m ²)	5,000 (50/m ²)	1,000 (10/m ²)	100 (1/m ²)	10 (.1/m ²)
Auger (10)	10,000	1.00 ^d	.50	.10	.01	.001
Auger (20)	2,500	1.00	1.00	.40	.04	.004
Shovel test (25)	1,600	1.00	1.00	.63	.06	.006
Shovel test (50)	400	1.00	1.00	1.00	.25	.025
Shovel test (100)	100	1.00	1.00	1.00	1.00	.100

^a Site dimensions: 10 × 10 × .5 m.

^b Depth of each probe except divot is 50 cm.

^c The potential probe locations are packed evenly within the 10 m²; spaces between potential probe locations are devoid of artifacts.

^d Probabilities are calculated as the number of artifacts divided by the number of probes per 10 × 10 m area.

(Table 4.12). Because they encompass more volume, the larger units have a greater likelihood of containing one or more artifacts when artifact frequency and density fall. Table 4.12 shows, for example, that when the model site contains 1000 artifacts (10/m² of surface area), a randomly placed auger 20 cm in diameter has a probability of .4 of containing an artifact. This is because only 1000 of the 2500 possible 20-cm-diameter augers in the site area contain artifacts. The other 1500 would be located in sterile soil between artifacts. Under the same site conditions, however, a 50-cm-diameter shovel test is certain to include more than one artifact (p = 1.0), because there are only 400 possible shovel tests in the area that also contains 1000 evenly distributed artifacts. Two suggestions are derived from Table 4.12. First, for sites with very low-average artifact densities, relatively large shovel tests might be the only effective subsurface probe. Second, and more important, the probabilities in Table 4.12 suggest that for sites or portions of sites with artifact frequencies of 50/m² or above, subsurface probes of relatively modest dimensions will be as effective as larger ones. Because the smaller probes can be dug, inspected, and recorded more quickly, they will be more efficient and a better choice of discovery technique for sites with sufficiently high artifact frequencies.

TABLE 4.13**Intrasite Variation in the Spatial Distribution of Lithic Artifacts^a**

Site (<i>N</i> shovel tests)	Shovel tests with <i>N</i> artifacts (%)				
	<i>N</i> = 0	1	2	3	≥4
19BN273 /275 (48)	23	19	13	8	35
19BN274 /339 (47)	32	26	9	9	26
19BN281 (75)	12	19	11	12	47
19BN282 / 283 / 284 (82)	22	13	15	9	41
19BN323 (44)	27	34	11	5	23
19BN333 / 336 / 337 (39)	26	28	10	13	21
19BN340 (27)	22	7	22	15	33
19BN341 (67)	28	19	9	9	34
19BN355 (22)	41	23	9	9	14
19BN356 (19)	42	39	16	5	0

^a Shovel tests systematically arrayed at intervals of approximately 6, 12, or 25 m. Data from 1980–1981 field seasons Cape Cod National Seashore Archeological Survey.

It is quite clear, unfortunately, that this model is burdened with two unrealistic assumptions. Artifacts within sites are neither uniformly distributed nor abundant. Table 4.13 shows typical variation in spatial distribution both within site areas and among sites. These data suggest, for example, that between 12 and 42% of the areas of these sites are devoid of artifacts. Variations in artifact abundance also are substantial (Table 4.14), with the variances in artifact frequency among equal-size test units commonly exceeding the mean by a factor of 2 or more. The sites' values of the variance/mean ratio and the negative binomial parameter *k* (Table 4.14) also suggest substantial spatial clumping of lithic artifacts. Values greater than 1.0 for the variance/mean ratio suggest an aggregated spatial pattern. For *k*, low values indicate pronounced spatial clumping (Pielou 1977:124–128).

These data reveal the gap between the simple site model described above and archaeological reality. Nonetheless, the model points out the relationship between artifact density and probe size. This can be explored further, along with the relationship between site size and discovery using another set of archaeological site data, this time from southeastern Massachusetts (Tables 4.15 and 4.16). The site data display a wide range of values for site area, average artifact frequency, and percentage of site area with relatively high artifact frequency (i.e., ≥16 artifacts/m², a value chosen for convenience of computing). The estimated number of successful shovel tests takes account of the intrasite spatial variation in artifact abundance. In deriving the estimates Thorbahn (n.d.:17–24) properly assigned lower probabilities of successful discovery to the percentage of shovel tests expected to be placed within the portions of sites containing few or no artifacts. The estimated number of successful tests is based upon 10 shovel tests placed randomly in each hectare of the study area.

TABLE 4.14

Intrasite Variation in the Abundance of Lithic Artifacts^a

Site (<i>N</i> of shovel tests)	Lithic artifacts per shovel tests		Variance/mean ^b	<i>k</i> ^c
	\bar{x}	s^2		
19BN273 / 275 (48)	2.9	8.6	2.96	1.48
19BN274 / 339 (47)	2.1	5.7	2.71	1.23
19BN282 / 283 / 284 (82)	4.3	22.8	5.30	.99
19BN323 (44)	2.8	20.9	7.46	.43
19BN333 / 336 / 337 (39)	3.0	16.2	5.40	.68
19BN340 (27)	3.3	12.6	3.82	1.17
19BN355 (22)	1.6	5.4	3.38	.67
19BN356 (19)	.8	.8	1.00	0.00

^a Shovel tests with diameters of approximately 40 cm. Data from 1980–1981 field seasons Cape Cod National Seashore Archeological Survey.

^b s^2/\bar{X} (Pielou 1977:124–126)

^c $k = \bar{X}^2/(s^2 - \bar{X})$ (Pielou 1977:128–134; Nance 1983).

TABLE 4.15

Effects of Site Size, Artifact Abundance, and Shovel Test Size on Discovery^a

Site number	Site area (hectares)	Average artifacts/m ²	% of site area with artifacts > 16/m ²	Estimated number of successful shovel tests ^b (10/hectare)	
				25-cm diam.	50-cm diam.
7AP	1.594	64.6	58.3	10.1	11.2
7CP	1.086	7.1	8.3	2.3	3.9
7DDP	.789	71.7	64.2	5.5	5.9
7GP	.112	35.0	64.5	.8	.8
7HHP	.829	60.3	60.	5.4	6.0
7KP	2.054	72.4	65.3	14.4	15.5
7MP	1.297	28.5	26.7	4.8	6.5
7PP	.285	14.5	14.5	.8	1.2
7RP	.167	22.8	48.9	1.0	2.0
7SP	.176	101.3	71.4	1.4	1.4
7TP	.188	12.1	9.1	.4	.7
7UP	1.647	7.2	10.2	3.7	6.1
9DP	.029	128.9	67.7	.2	.2

^a Data from I-495 Archaeological Project, Public Archaeology Laboratory, Brown University (Thorbahn n.d.: Tables 2 and 3).

^b Estimates based upon number of tests that would be placed randomly within a site area, multiplied by the probability that the test would contain at least one artifact. Ten shovel tests randomly placed within each hectare.

TABLE 4.16

Correlation Matrix of Table 4.15 Variables

	Site area	Artifacts/m ²	% Area with ≥ 16 artifacts/m ²	Number of successful tests	
				25 cm	50 cm
Site area	—	—	—	—	—
Artifacts/m ²	-.14	—	—	—	—
% Area with ≥ 16 artifacts/m ²	-.12	.83	—	—	—
Successful tests(25 cm, 10/ha)	.85	.19	.30	—	—
Successful tests(50 cm, 10/ha)	.92	.09	.19	.99	—

The correlations between variables (Table 4.16) indicate that site area is highly and positively correlated with the number of shovel tests that recover artifacts—.85 for 25 cm diameter tests and .92 for tests 50 cm in diameter. Neither average artifact frequency nor percentage of site area with relatively high artifact density, are correlated substantially with the number of successful tests. This suggests that it is the area over which a site extends rather than the density of artifacts within it that most strongly influences the probability of discovery. A closer look at this particular data set confirms this. Four of the 13 sites would not be detected by shovel tests with 25 cm diameters; that is, these 4 have estimated numbers of successful tests that are less than 1.0. Among these 4, the ranges of values for average artifacts per m² and percentage of site area with relatively high artifact density are 12.1–128.9 and 9.1–67.7 respectively. These are not out of line with the value ranges of these variables for all 13 sites: 7.1–128.9 artifact/m² and 8.3–71.4% of the site area. On the other hand, the 4 sites are among the smallest in area of the 13. All 4 are below .3 ha in area, whereas only 3 of the remaining 9 sites have such small areas.

In only one case, Site 7PP, does increasing the shovel test size to a 50 cm diameter increase the estimated number of successful shovel tests to above 1.0. It is interesting that Site 7PP has relatively low values for average artifacts per m² and percentage of site area with relatively high artifact density. Analysis of the abstract model-site data above (Table 4.12) indicates that sites with such characteristics would have better chances for discovery using larger shovel tests.

The Number and Spacing of Probes

The site data presented above (Tables 4.13–4.15) demonstrate on a larger scale the problem of discovering relatively rare items that Nance (1981:153–160; see also Nance 1983) has discussed in detail on the intrasite level. A site such as 9DP (Table 4.15), which occupies under 3% of a hectare, would be difficult to find, given the constraints of the survey design, despite its abundance of artifacts and high artifact density. Because archaeologists have no control over site size, they can only improve their ability to discover small sites by increasing the number of shovel tests. Increasing the size of individual tests might help in some cases, such as with Site 7PP (Table 4.15). In general, however, more tests, whether by using shorter intervals in a systematic array or a larger number of randomly placed tests per unit of area, are the key to improving the likelihood of discovering the small sites. Furthermore, the intensity of effort might have to be substantially increased. In the case at hand, a doubling of the number of tests per

hectare from 10 to 20 would result in all but two of the sites, 7TP and 9DP (Table 4.15), having estimates of greater than 1.0 for the number of successful shovel tests (25 cm diameter). Another doubling to 40 tests/hectare would give 7TP a value of 1.6 estimated successful tests, but a value of only .79 for 9DP. The latter site would still have a value less than 1.0 for estimated number of successful tests if the intensity were 50 tests/hectare. The value finally tops 1.0, specifically 1.17, for a test intensity of 60 shovel tests/hectare. For easier comprehension of the effort necessary for comparable systematic and simple random shovel test arrays, Table 4.17 shows the approximate interval between systematically placed tests at the levels of test intensity referred to above.

Little has been said here directly about the effect of the spatial arrangement of probes upon site discovery. The effectiveness of specific arrangements of probes depends upon the specific distribution of the site constituent being sought in particular situations. Therefore, I concentrate here on how variations in the number of probes affect the likelihood of site discovery. There are, however, several general considerations about the arrangement of probes presented below. The choice of whether to use an arrangement that is systematic, simple random, or some combination of these should be guided by the project's goals, the expected distribution of the constituent being sought, and logistics. No particular type of arrangement has a monopoly on effectiveness.

TABLE 4.17

Test Intervals for Comparable Numbers of Tests/Hectare

Tests/hectare	Number of m ² for which test is centroid	Interval between tests (m) ^a
10	1000	32
16	625	25
20	500	22
25	400	20
40	250	16
50	200	14
60	167	13

^aApproximate.

A systematic arrangement will provide the most even coverage of a given area or sample unit (McManamon 1981a, 1981c), although, as Tables 4.15 and 4.17 and the preceding discussion have shown, the interval among probes might have to be very small to discover rare or highly clustered constituents. A danger of using systematic arrangements is that the interval among probes might inadvertently match a set interval between archaeological remains, resulting in the probes consistently missing their targets. This seems more likely to be a potential problem when features are the target constituent because several types of features (e.g., hearths, house floors, postmolds) might have intrasite distributions that are at least roughly systematic. Artifact intrasite distributions, on the other hand, seem less likely to be arranged systematically and probably present no such problem for the use of a systematic grid.

A systematic grid with adjacent lines of probes offset or staggered has a more economical packing of probes (Krakker *et al.* n.d.). The offset grid evenly and equivalently covers an area or sample unit with fewer probes than would be required by a more traditional grid with evenly aligned probes.

With proper planning, an arrangement of randomly located probes can provide data suitable for estimation of the overall frequencies and distribution of archaeological remains in a study area. Simple random arrangements of probes usually should be used only when data are to be used for estimation and the probes are themselves the sample units (Nance 1980b, 1983). A simple random arrangement frequently covers an area very unevenly. Sites in portions of the area not covered by the probe arrangement go undiscovered. This will cause problems for estimation of site frequencies when the sample units are the areas to be covered by the probe grids rather than the probes themselves (McManamon 1981c, 1982). When a site constituent that is believed to have a systematic arrangement is being sought, yet roughly even coverage of an area or sample unit is desired, an arrangement with random and systematic aspects, such as a stratified, unaligned random grid may be the answer (Spurling 1980).

Returning again to the relationship between the number of probes and site discovery, obviously substantial effort would be necessary to ensure the discovery of all the types of sites represented in [Table 4.15](#). Unless a complete inventory of sites is required, however, less time-consuming means are available in many instances to estimate the frequencies of sites too small to be discovered consistently.

The estimated numbers of successful shovel tests discussed above are, after all, only approximations that should hold over the long term. Some small sites will be discovered even though the test interval or intensity is not adequate to discover all of them (Krakker *et al.* n.d.:6; Lovis 1976; McManamon 1981c: 195–204; Nance 1979). The characteristics of these sites (e.g., site size and artifact density) combined with the frequency with which they actually were identified can be used to estimate the numbers of such sites still undetected.

If for some reason no sites below the size expected to be discovered have been detected, it still is possible to determine the likelihood that sites of a certain size and artifact density do exist but have been missed by the discovery technique used. Stone (1981a:45–49) has demonstrated the use of the Poisson distribution for evaluating this type of negative evidence. He also has applied the Poisson distribution for the more general case of evaluating the probability of success of individual shovel tests and the estimation of necessary sample sizes for different levels of discovery probability (Stone 1981b; see also, Krakker *et al.* n.d.).

This section has identified and discussed factors that affect the probability that sites will be discovered by subsurface probes. Although some insights have been noted, there have been no comprehensive revelations. This is dictated by the nature of the problem. Whether or not a site of certain size and artifact density is discovered depends upon the specific technique used and the method in which it is applied. Happily, ways of conceptualizing and resolving this problem is receiving more prominent, extended, and sophisticated attention within the discipline. Such study can only improve the ability of archaeologists to interpret and explain the past.

SUMMARY AND PROGNOSIS

There is no general resolution to the problem of site discovery, but the fact that it is increasingly recognized as a problem to be dealt with explicitly is an improvement (e.g., Carr 1982; Lynch 1980, 1981; Nance 1980b, 1981, 1983; Rice *et al.* 1980; Schiffer *et al.* 1978; Stone 1981 a, b). This chapter is, I hope, a clear introduction to the problem, to some of the approaches and perspectives about it, and to the methods and techniques that individually or in combination can solve it.

The concept of site obtrusiveness (Schiffer *et al.* 1978:6) was introduced at the beginning of this chapter. It has two aspects: (1) the ease with which site contents are detectable, and (2) the type of technique(s) necessary to discover the site or sites of interest.

The first principal section of this chapter considered the intersite frequency, intrasite abundance, and intrasite spatial distribution of the physical and chemical constituents believed to be most common among archaeological sites. The suitability of different site constituents as targets for discovery efforts depends upon their frequency among and within sites, and their intrasite spatial distribution. Constituents that are abundant and widespread, in most cases, will be more easily discovered than those that are not.

Accessible and clear descriptions of archaeological remains in the terms necessary for judging the obtrusiveness of different constituents are surprisingly rare, but some generalizations have been gleaned from those that are available. Artifacts, the portable products and by-products of human activities, are the most common type of constituent among sites. Within most archaeological sites, artifacts are the most abundant and widespread type of constituent. Other constituents are features, anthropic soil horizons, and human-induced anomalies that can be detected by chemical or instrument tests and analysis. In many cases, the anomalies are related to features or soil horizons. Features and anthropic soil horizons with large amounts of organic remains, for example, cause anomalously high chemical scores. Other features and horizons that are distinctly different in composition from the surrounding soil matrix of the site can cause anomalies that are detectable using resistivity magnetometry, subsurface radar, and remote sensing analysis. Not all features or soil horizons, however, cause anomalies, at least easily detectable anomalies (Carr 1982). Easily detectable chemical or instrument anomalies are expected to occur in a relatively small portion of the total number of sites in the archaeological record. In a smaller portion of sites, for example, than contain features or anthropic soil horizons because it is subsets of the total number of features and horizons that cause the chemical and instrument anomalies. In general, then, artifacts are found in most sites, features, and anthropic soil horizons in a smaller proportion of sites, and chemical and instrument anomalies in a yet smaller proportion.

Regarding intrasite abundance and distribution, artifacts again top the list with features, followed by anthropic soil horizons. The multisite examples of the other two types of site constituents considered in the first section did not permit comparisons with the first three types or each other. The examples did point out, however, an additional drawback of aiming discovery efforts at chemical and instrument anomalies. The detection of most humanly induced archaeological chemical or instrument anomalies requires substantial, detailed data about the natural chemical, textural, and moisture characteristics of the soil throughout a study area. The collection of these detailed data for intrasite analysis is far more feasible (Carr 1977, 1982) than for discovery investigations in large study areas. Site constituents that can be detected using remote sensing analysis usually do not require this extensive background data; however, they typically require very good visibility conditions. Even a slight forest or shrub canopy can hide the anomalies from sight, preventing discovery.

All other things equal, artifacts should be the site constituent that discovery efforts aim to detect. All other things often are unequal, of course, and archaeologists quite properly have aimed discovery efforts at other site constituents to overcome special constraints or focus on particular types of sites (Bruder *et al.* 1975; Chapman 1977, 1978; Ehrenhard 1980; Harp 1974, 1977; papers in Lyons 1976, Lyons and Ebert 1978, and Lyons and Hitchcock 1977). To emphasize a point made at the beginning of this article, project goals and limitations ultimately should determine the discovery technique or techniques used. The process and reasons for reaching the

decision should be explicit because the choice of technique affects so strongly the types of sites that will be discovered.

More data about site constituents presented clearly and quantitatively, are needed. As the preceding section of this chapter showed, a host of questions about the effectiveness and efficiency of different discovery techniques cannot be answered in detail without such data. The probabilities of successful discovery presented in the preceding consideration of the effectiveness of subsurface probes required assumptions about the size, artifact density, and artifact distribution within sites. The accuracy of the assumptions that were used to represent sites in the archaeological record is unclear. Archaeologists' ability to resolve questions about method and technique will improve substantially as clear and reliable data describing the physical and chemical characteristics of the record become better known. The progress being made along these lines is encouraging but much more attention is necessary.

The second major section of this chapter described and evaluated a variety of archaeological field techniques for their effectiveness in site discovery investigations. Subsurface probe techniques received the most attention. Chemical tests and instrument techniques such as resistivity, magnetometry, and subsurface radar are more likely to be useful for intrasite analysis, given the detailed background data necessary for their accurate analysis, the logistical problems their application to large survey areas would involve, and the kinds of anomalies they can detect. Remote sensing techniques in general can be effective for site discovery in areas of good surface visibility when the sites are on or near the surface and contain large, distinct features, preferably former structures or anthropic soil horizons. Several exceptions were noted in which surface visibility was poor, that is, the study areas had dense vegetation but slight elevations of site areas caused differences in vegetation or vegetation growth that were easily detected by aerial photographic analysis (Bruder *et al.* 1975; Ehrenhard 1980; Newman and Byrd 1980).

As a group, subsurface probes seem most widely applicable for site discovery because, in general, they can detect the most-common site constituents: features, anthropic soil horizons, and, especially, artifacts. Among subsurface probes, shovel tests probably are the most effective overall for site discovery. Their effectiveness varies, however, according to (1) the size and intrasite artifact abundance and distribution of the target sites and (2) the volume, (3) number, and (4) arrangement of the shovel tests.

If the size and intrasite artifact abundance and distribution of target sites is known or can be estimated, the likelihood of site discovery given various sizes and numbers of tests is predictable. Considering the small size or intrasite clustering of some sites, however, the total discovery of all types of sites for even relatively small study areas where subsurface probes are necessary will require substantial diligence, effort, and funding.

This fact raises the issue of archaeological sampling. Many of the discovery techniques discussed here are very time consuming and, therefore, very costly to apply intensively over large areas. One solution, usually a poor one, is to apply a technique extensively; that is, to increase intervals between tests, reducing the number of tests per unit area. This will result in the discovery of only sites with very large areas.

A solution that is likely to provide more accurate and ultimately more useful results is to examine a portion, or sample, of the study area intensively, then use the sample data to estimate the characteristics of the archaeological record in the entire area. If probability sampling is used, the precision of estimates usually can be calculated objectively, but even informed, explicit judgment sampling can derive estimates that can be qualitatively evaluated. The discovery of rare sites, in

any case, probably will require informed judgment sampling (Schiffer *et al.* 1978:4–6). Study areas can be stratified to accommodate combinations of probability and nonprobability sampling. Strata with high expected site-densities can be sampled using a probability design with other strata sampled judgmentally. Furthermore, explicit sampling designs, probability or otherwise, need not be limited to arid environments with clear surface visibility, as recent successful applications in the thick brush, shrubs, and forests of Kentucky and Massachusetts illustrate (McManamon 1981b, 1981c, 1982; Nance 1980a, 1980b, 1983).

As archaeologists undertake more site discovery investigations in regions where discovery is difficult, seeking sites that are hard to find, they must grapple with a variety of concerns. Among these are the goals of their investigations, the characteristics of the sites they seek, the effectiveness for site discovery and logistical requirements of field techniques available to them, and the appropriate sampling method for applying the chosen technique. The heartening increase in the numbers of archaeologists involved in such deliberations and the quality of the recent grappling make site discovery an exciting frontier of contemporary archaeological theory, method, and technique.

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